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ANNUAL PROGRESS REPORT

Fiscal Year 1980

(1 October 1979 - 30 September 1980)

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

1 October 1980

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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A report of progress on the research program of the US Army Research Institute of Environmental Medicine for Fiscal Year 1980 is presented, as follows:

Program No.	Project No.	Task No.	Title
6.11.01.A	3A161101A91C	00	In-House Laboratory Independent Research
6.11.02.A	3E161102BS08	00	Defense Research Sciences, Army
6.27.77.A	3E162777A845	00	Environmental Stress, Physical Fitness and Medical Factors in Military Performance

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Electroencephalography
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Environmental Tolerance
Evaporation Cooling Index
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Fatigue
Frostbite
Heat Stress
Heat Stroke
Hepatic Necrosis
Load Carriage
Human Performances
Hypothermia
Hypoxia
Insulation
Job Tasks
Maximal O_2 Uptake
Metabolic Acidosis
Military Operations
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Motivation
Motor Activity
Muscle Fibers
Muscle Strength
Obesity
Peripheral Blood Flow
Physical Fitness
Physical Training
Psychomotor Function
Pulmonary Aterial Hypertension
Pulmonary Edema
Rating Scales
Respiratory Control
Survey Analysis
Sustained/Continuous Operations
Sustained Human Performances
Symptom Self-Reports
Team Performance
Terrain Coefficients
Thermal Exchange
Thermogensis
Thermography
Thermoregulation
Tolerance Predictions

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK, MASSACHUSETTS

01760

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

ANNUAL PROGRESS REPORT

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MEDICAL RESEARCH & DEVELOPMENT COMMAND

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US ARMY RESEARCH INSITITUTE OF ENVIRONMENTAL MEDICINE

(020)

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a. PRIMARY	61101A	3A161101A91C	00	020
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11. TITLE (Precede with Security Classification Code)* (U) Development of Survey Methodology for Analysis of Environmental Medical Illness and Risk (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 007900 Occupational Medicine; 012500 Personnel Selection, Training; 005900 Environmental Biology; 013400 Psychological; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
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19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2854

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

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NAME: DA

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Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Survey Analysis; (U)Symptoms Self-Reports; (U)Questionnaires/Interviews; (U)Climatic Exposure; (U)Health Risk Factors; (U)Rating Scales

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Current medical records do not adequately define the number and type of Army personnel who suffer environmentally-induced illness and injury. Data must be obtained on the population at risk, on treatment follow-up, on partially disabling symptoms which go unreported, on the nature of exposure, and on medical risk factors due to job assignment, individual background, physical condition, and related health behaviors.

24. (U) This work unit develops and pilot tests new methods for survey sampling and epidemiologic studies of Army personnel exposed to specific climatic extremes and physical demands in training exercises. Questionnaires, structured interviews, personnel and medical record survey forms and observation procedures for the collection of subjective and objective data regarding exposure, symptoms, incapacitation, illness and injury under specific Army environmental conditions are designed, sample tested, revised and validated for subsequent routine use in other work units.

25. (U) 79 10 - 80 09 A cold weather background questionnaire and standard admissions log forms for use in medical treatment facilities were prepared and sample tested prior to use in a REDCOM exercise. Case record and environmental exposure and symptoms questionnaires, plus formal written instructions and aides for administration was designed and packaged in durable form for use by unit medics in a field study. Further improvements were made based on field experience. One questionnaire (the ESQ) was modified for scoring by optical scanner and tested; software for scoring conventional questionnaires rapidly with an X-Y plotter was written and tested. A videotape was prepared to train laboratory personnel in how to conduct structured survey interviews in field studies. Two versions of a Cold Weather Survival Quiz were compiled for use in evaluating training, and similar questionnaires for hot weather are being developed.

*Available to contractors upon originator's approval.

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Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	020 Development of Survey Methodology for Analysis of Environmental Medical Illness and Risk
Study Title:	S/A
Investigators:	James B. Sampson, Ph.D., James W. Stokes, LTC(P), MC

Background:

Research methods of environmental medicine involve experimental studies which are valuable and necessary for answering important questions of basic mechanisms and processes of climatic stress. However, the experimental techniques which call for careful control of many variables are difficult to implement when trying to assess problems during military operations. Field research requires different methodology because of the lack of sufficient controls. An alternative is to rely on existing records to extract information on medical problems occurring in conditions of extreme weather. However, this too has limitations. Current medical records do not adequately define the number and type of Army personnel who suffer environmentally-induced illness and injury. Data are usually lacking on the population at risk, on treatment follow-up, on partially disabling symptoms which go unreported, on the nature of exposure, and on medical risk factors due to job assignment, individual background, physical condition, and related health behaviors. A third alternative develops and tests new methods for survey sampling and epidemiologic studies of Army personnel exposed to specific climatic extremes and physical demands in training exercises. Questionnaires, structured interviews, personnel and medical record survey forms and observation procedures can be used to collect subjective and objective data regarding exposure, symptoms, incapacitation, illness and injury under specific conditions. These survey instruments must be designed, sample tested, revised and validated for subsequent routine use in other work units.

Progress:

It is the purpose of this project to provide the methods for a better estimation of the Army's personnel preparedness for a variety of extreme conditions. Three questionnaires have been compiled which were designed to evaluate knowledge of cold weather survival. Copies were sent to the Army's Northern Warfare Training Center in Alaska for evaluative testing. Pilot tests will also be conducted on untrained civilians for comparison with Army personnel. The Environmental Background Survey Form, which assesses experience with climatic extremes, has been used in a number of studies including a recent study of Marines in Norway conducted by the Naval Submarine Medical Research Laboratory. Samples from two Army posts, one northern, one southern, indicates there may be regional biases in the distribution of experience of personnel. The distributions are such that individuals from southern climates are more likely to be assigned to southern posts and those from northern climates to northern posts. Given that a high proportion of the Army's personnel in the field are from a southern climate (estimated at 60%) these results suggest that a majority do not have and are not likely to get any significant experience with cold weather. Therefore, this would contraindicate the frequently recommended policy of personnel selection of cold climates since more personnel, not less, need to gain cold weather experience. However, more surveys are required for more definite exposure.

Improved versions of the Medical Record Log used in the Empire Glacier '80 study have been designed for such exercises as Brave Shield and Brim Frost. These forms are intended to help in reducing omissions and errors in field data collection. A modified medical case record log and an Environmental Exposure Checklist were designed and packaged in durable folders along with instructions and administration aids for use by unit medics (MOS 91B) in the field; this was pilot tested during a TCATA field experiment involving mechanized infantry in smoke environments at Fort Hood, TX. Procedures for collecting essential population statistics and applying particular sampling techniques have not yet been worked out fully but are an important aspect of this project. Such procedures require coordination with personnel statisticians who have the information necessary for conducting scientific sampling.

The Environmental Symptoms Questionnaire has recently been modified to include symptoms not previously covered, such as nose bleeding, loss of appetite, muscular stiffness, and a few others, for a total of 11 more items. The format of the questionnaire remains the same, and is still only two pages long. This new version has been administered during the recent Pikes Peak study conducted by the Altitude Research Division.

Publication:

Sampson, J. B. and J. L. Kobrick. The environmental symptoms questionnaire: revisions and new field data. Aviat. Space and Environ. Med., 51:872-877, 1980.

LITERATURE CITED

Dean, L. M. and K. Laxar. Morbidity forecasting and emergency medical care in cold weather operations. Paper presented at the American Psychological Association Meeting, Montreal, Canada, September 1980.

(022)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION: DA OB 6132	2. DATE OF SUMMARY: 80 10 01	REPORT CONTROL SYMBOL: DD-DR&E(AR)636

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11. TITLE (Precede with Security Classification Code)

(U) Ventilatory Control Mechanisms at High Altitude (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

012900 Physiology; 005900 Environmental Medicine; 016200 Stress Physiology

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21. GENERAL USE

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22. KEYWORDS (Precede EACH with Security Classification Code) (U)Chronic Hypoxemia; (U)Respiratory Control System; (U)Peripheral and Medullary Chemoreceptors; (U)Acute Metabolic Acidosis

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The physiologic processes which control ventilation of man at high altitude are not fully understood. The objective of this work unit is to gain new knowledge of ventilatory control, with emphasis on adaptations within the control system during exposure to chronic hypoxemia, as experienced during sojourn at high terrestrial altitudes. A thorough understanding of this aspect of altitude physiology is essential in defining new approaches for enhancing adaptation of the soldier to high terrestrial elevations.

24. (U) An integrated program is under way to analyze contributions of both the carotid body and medullary chemoreceptors to the ventilatory adaptations to hypocapnic hypoxia, including interactions between the two chemoreceptors.

25. (U) 79 10 - 80 09 Changes in pulmonary ventilation were measured in unanesthetized goats in response to the onset of acute metabolic acidosis (AMA). The ventilatory changes were related to alterations in the composition of arterial blood and cisternal cerebrospinal fluid (CSF). Studies were repeated in the same goats after carotid-body denervation to evaluate the contribution of the peripheral chemoreceptors in the ventilatory response to AMA. Ablation of carotid bodies produced hypoventilation in goats at rest. Thus, the peripheral chemoreceptors appear to contribute significantly to the ventilatory drive of normoxic goats at rest. AMA produced comparable degrees of hyperventilation in goats with intact and ablated carotid bodies despite a slight alkaline shift in CSF pH. Therefore, the stimulus for hyperventilation under these conditions does not appear to arise in the carotid bodies or in the ionic composition of the CSF. Increased acidity of the cerebral interstitial fluid surrounding the central chemoreceptors remains a possible stimulus for the hyperventilation in AMA. This unit terminated on 30 Sep 80, but work will be continued in FY81 under a core unit, BS10/CA, (DAOA 6144).

*Available to contractors upon originator's approval

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	022 Ventilatory Control Mechanisms at High Altitude
Study Title:	Role of Cerebral Fluids in Respiratory Adaptations to Acute Acid-Base Imbalance
Investigators:	Vladimir Fencl, M.D., Ronald A. Gabel, M.D., John C. Donovan, CPT, VC, and Richard A. Steinbrook, M.D.

Background:

With acutely developing acid-base disturbances of metabolic origin, such as lactic acidosis during exercise beyond anaerobic threshold, respiratory "compensations" are known to occur rapidly (1). Hyperventilation and lowering of Pa_{CO2} develops within minutes after the onset of an acute lactic acidosis. Regulatory mechanisms responsible for the respiratory adaptations in acid-base disturbances of metabolic origin are still subjects of controversy. In steady-state metabolic acidosis (or alkalosis) of several days' duration, $[H^+]$ in the fluid surrounding the central chemosensitive areas (2,3) is thought to be a partial (4,5) or single (6,7) determinant of the level of pulmonary ventilation.

Mitchell et al. (4,5) ascribed a predominant role for the peripheral (carotid) chemoreceptors in the development of hyperventilation in response to metabolic acidosis. According to their theory, a lowered pH in arterial blood initially stimulates the peripheral chemoreceptors. The subsequent increase in pulmonary ventilation lowers P_{CO2} in both blood and CSF, thus producing a "paradoxical alkaline shift" (8) in CSF during the early phase of metabolic acidosis. Mitchell et al. reasoned that this alkalotic CSF pH, in turn, somewhat depresses the pulmonary ventilation through its action on the central chemosensitive areas, thus inhibiting complete expression of the effect of acidosis on the peripheral chemoreceptors. Full-scale hyperventilation is established only after $[HCO_3^-]$ in CSF is lowered as a consequence of the metabolic acidosis in blood.

In contrast, in the model proposed by Pappenheimer et al. (6), the hyperventilation observed in chronic steady-state metabolic acidosis is attributed entirely to the increased acidity of the cerebral interstitial fluid (cISF) that surrounds the central chemosensitive areas. These authors found the ionic composition (and acidity) of the cISF to be similar to that of the CSF in steady chronic acidosis or alkalosis of metabolic origin. In this model, no specific role is ascribed to the peripheral chemoreceptors. Pappenheimer et al. did not consider transient situations in acute acid-base imbalance.

We have measured changes in pulmonary ventilation in unanesthetized goats, in response to an acute onset of metabolic acidosis, relating the ventilatory changes to alterations in the composition of arterial blood and cisternal CSF. To evaluate the contribution of the peripheral chemoreceptors in the ventilatory response to acute metabolic acidosis, we repeated the studies in the same goats after peripheral carotid denervation.

Progress:

We prepared four goats by implanting cisternal guide tubes for repeated aseptic sampling of cisternal CSF, according to the method of Pappenheimer et al. (9). We also provided each animal with a skin-denervated carotid artery loop to facilitate easy and painless sampling of arterial blood. At least three weeks were allowed for healing and postoperative recovery.

Before each experiment we: 1) inserted a needle of adjustable length through the guide tube into the cisterna magna; 2) inserted a 3 cm plastic cannula-over-needle percutaneously into the carotid artery in the loop; and 3) inserted a 20 cm plastic cannula over a metal guide wire placed percutaneously into one of the external jugular veins, under local anesthesia.

Ventilatory measurements were made with the goat wearing a tight-fitting latex mask, while end-tidal P_{CO2} ($P_{ET_{CO2}}$) was continuously recorded using a Beckman LB-2 infrared analyzer or a Perkin Elmer MGA 1100 Mass Spectrometer. Expired gas during ventilatory measurements was collected, and measurements of mixed-expired P_{CO2} were used to calculate carbon dioxide production ($\dot{V}_{CO2}$). After establishing a quiet steady state of ventilation, samples of arterial blood and cisternal CSF were withdrawn for the analysis of P_{CO2} and pH in blood and CSF, and P_{O_2} and chloride ion concentration in blood. After another period of quiet resting breathing, during which $\dot{V}_E$, $P_{ET_{CO2}}$, and $\dot{V}_{CO2}$ were again measured, repeat blood samples were taken to increase confidence that representative values were obtained.

After the steady-state breathing studies were completed, two or more carbon dioxide rebreathing studies (10,11) were performed, starting with 3L of 7 percent carbon dioxide, balance oxygen, in the bag-in-box. An arterial blood sample was withdrawn during the plateau of $P_{ET_{CO_2}}$ early in rebreathing and again near the end of the rebreathing period. Ventilation was analyzed by computer on a breath-by-breath basis, and $\dot{V}_E$ was plotted against both Pa_{CO_2} and $P_{ET_{CO_2}}$. Using standard techniques of linear regression, the slopes and x-intercepts of curves representing ventilatory responses to increasing P_{CO_2} were determined.

After the above control studies, 15 ml of 0.2N hydrochloric acid (HCl) per kg of body weight were infused through the jugular venous catheter at 15 ml/min. This dose usually produced a base deficit of approximately - 10 mM/l. If the base deficit fell short of this goal, additional 0.2 N HCl was infused at the same rate. Pilot studies showed that such an infusion led to a stable metabolic acidosis for long enough to repeat all steady-state ventilatory rebreathing experiments and the sampling of arterial blood and of CSF, exactly as carried out during the control period.

After successful completion of the above studies, each goat was operated upon under general anesthesia for bilateral excision of the carotid-body chemoreceptors. At least two weeks later, effectiveness of the chemodenervation was tested by injection of a bolus of potassium cyanide, 0.05 mg/kg of body weight, through a pulmonary artery catheter inserted percutaneously through an external jugular vein, using a Cordis sheath. After another appropriate recovery period following confirmation of carotid denervation (at least a week), the above experimental protocol (studies before and after HCl infusion) was repeated in its entirety.

The first line in Table 1 shows that the goats with intact carotid bodies were normoxic and in normal acid-base balance. In these goats, standard HCl infusion led to a metabolic acidosis (to base deficit-10 mM/l) with acidemia (pH_a = 7.284 from 7.481 control). Ventilation increased so as to reduce mean Pa_{CO2} from 36.9 to 33.0 torr ($p < 0.001$). Since $\dot{V}_{CO2}$ was the same after as before HCl infusion (182 ± 13 and 187 ± 14 ml/min STPD, respectively), a significant hyperventilation was present. In CSF, P_{CO2} fell as well, from 43.4 to 39.0 torr ($p < 0.001$), while $[HCO_3^-]$ fell only from 23.5 to 22.7 mM/l ($p < 0.01$); pH changed in the direction of the "paradoxical shift" (8), from 7.289 to 7.305 (not statistically significant).

After ablation of the carotid bodies, the resting P_{CO2} in the control condition (before HCl infusion) was significantly higher than when carotid bodies were present (39.7 and 36.9 torr, respectively, $p < 0.05$). Since $\dot{V}_{CO2}$ was similar before and after denervation (187 ± 14 and 171 ± 24 ml/min STPD, NS) this represented hypoventilation after ablation of the carotid bodies. This hypercapnia produced a mild respiratory acidosis (pH_a 7.399, compared with 7.418 in intact goats, $p < 0.01$). There were no significant changes in CSF P_{CO2}, pH, or HCO_3^- with carotid body ablation.

When the standardized dose of HCl was given, the denervated goats dropped their Pa_{CO2} an average of 4 torr (from 39.7 to 35.7 torr, $p < 0.01$), which was similar to the 3.9 torr reduction in Pa_{CO2} with HCl with carotid hodies intact. The extent of acidosis was similar in intact and denervated goats (B.E. -10.2 and -9.0 mM/l, respectively), as was the extent of acidemia (pH 7.284 and 7.286, respectively). In CSF, P_{CO2} went from 44.7 to 41.6 torr ($p < 0.01$), $[HCO_3^-]$ from 24.6 to 23.6 mM/l (NS), and pH again suggested "paradoical shift" (8), from 7.305 to 7.311 (NS).

TABLE 1

Composition of arterial blood and CSF in goats; effect of carotid body ablation, and infusion of HCl. Means ± S.E.

		Arterial blood					CSF		
		P_{CO2}	P_{O2}	pH	BE	$[HCO_3^-]$	P_{CO2}	pH	$[HCO_3^-]$
Carotid bodies intact	Control	36.9	94.1	7.418	-0.8	23.0	43.4	7.289	23.5
(n = 5)		±0.7	±1.7	±0.004	±0.5	±0.5	±0.7	±0.011	±0.3
	After HCl infusion	33.0	96.5	7.284	-10.2	15.0	39.0	7.305	22.7
		±0.8	±2.2	±0.011	±0.6	±0.6	±0.8	±0.005	±0.2
Carotid Bodies ablated (n = 4)	Control	39.7	85.5	7.399	-0.7	23.6	44.7	7.305	24.6
		±0.7	±1.5	±0.004	±0.5	±0.5	±0.5	±0.011	±0.4
	After HCl infusion	35.7	91.4	7.286	-9.0	16.2	41.6	7.311	23.6
		±1.0	±1.7	±0.010	±0.6	±0.6	±0.6	±0.011	±0.2

TABLE 2

Ventilatory response to CO_2 rebreathing in goats

$P_{ET_{CO2}}$ at $\dot{V}_E$ = 30 l/min BTPS (torr)

		n	mean	SD	SE
Carotid bodies intact	Control	18	61.0	$\pm$3.1	0.1
	After HCl	22	56.8	$\pm$4.0	0.9
Carotid bodies ablated	Control	24	65.9	$\pm$3.0	0.6
	After HCl	22	62.6	$\pm$3.2	0.7

In Table 2 is a summary of the changes in the ventilatory responses to CO_2 rebreathing of the goats under the four conditions of the study. Position and slope of the CO_2 response curves were evaluated concurrently by comparing mean P_{CO2} values at $\dot{V}_E$ 30 l/min ($P_{CO2}/30$). Carotid body ablation produced a significant increase in $P_{CO2}/30$ from 61.0 to 65.9 torr, ($p < 0.001$). This finding corroborates the conclusion drawn from Table 1 that carotid-body ablation produced hypoventilation. Acute standardized metabolic acidosis produced by HCl infusion shifted the CO_2 response curves to lower P_{CO2} values, whether or not the carotid bodies were present. This shift produced by HCl infusion was similar in goats with intact and ablated carotid bodies (3.0 and 4.1 torr, respetively; NS).

We conclude:

1. Ablation of carotid bodies produced hypoventilation in goats at rest. Thus, the peripheral chemoreceptors appear to contribute significantly to the ventilatory drive of normoxic goats at rest.

2. Acute metabolic acidosis produced comparable degrees of hyperventilation in goats with intact and ablated carotid bodies, despite a slight alkaline shift in CSF pH. Therefore, the stimulus for hyperventilation under these conditions does not appear to arise in the carotid bodies or in the ionic composition of the CSF. Increased acidity of the cerebral interstitial fluid surrounding the central chemoreceptors remains a possible stimulus for the hyperventilation in acute metabolic acidosis.

Publication:

Fencl, V. and R. A. Gabel. Respiratory adaptations in acid-base disturbances: Role of cerebral fluids. Contr. Nephrol., Karger, Basel, Switzerland, 21:145-149, 1980.

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(024)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6125	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61101A	3A161101A91C	00	024
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Regulation of Body Weight (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012400 Personnel selection and maintenance (medical); 012900 Physiology; 003500 Clinical medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	0.3	1
	CURRENT 81	1.0	7

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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NAME:* GOLDMAN, Ralph F., Ph.D.

TELEPHONE: 955-2831

SOCIAL SECURITY ACCOUNT NUMBER

ASSOCIATE INVESTIGATORS

NAME: DANFORTH, E. (U of VT Med School) DA

NAME: LANDSBERG, L. (Harvard Med School)

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Fitness; (U)Body Weight Regulation; (U)Obesity; (U)Catecholamines; (U)Thermogenesis; (U)Thyroid

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) In collaboration with clinical research groups, assess the metabolic (USARIEM) and endocrine (clinical collaborators) responses of individuals with no body fat (lipoadystrophy), limited body fat (anorexia nervosa and lipoatrophy), normal body fat but difficulties with weight regulation ("hard" and also "easy gainers") and excess body fat (obesity).

24. (U) Measure metabolic heat production and heat loss during exercise, pre- and post-prandial rest and basal conditions of such individuals on normal high and low caloric intake levels, with varied proportions of dietary carbohydrate, fat and protein, while simultaneously measuring their endocrine responses, with particular attention paid to thyroid regulation of body heat production and, consequently, body weight.

25. (U) 79 10 - 80 09 All necessary equipment has been delivered and is being calibrated. Technicians have been trained in the required measurements, at Vermont, and technicians are being trained at the NIH facility in Phoenix. As a result of simple exposures in the USARIEM cold room, the feasibility of studying non-shivering thermogenesis, and any defect in it as a contributor to obesity, has been adopted as a possible cause of obesity in humans. An extensive and detailed protocol for this first study has been completed and approved by the University of Vermont Clinical Research Center human use committee and also through Harvard Medical School human use committee and the NIH Pima Indian project human use committee.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.01A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	024 Regulation of Body Weight
Study Title:	Regulation of Body Weight in an Obese and Diabetic Inbred Human Population, the Pima of Arizona
Investigators:	Ralph F. Goldman, Ph.D., Elliot Danforth, M.D., Orrin Tulp, M.D., Ethan Sims, M.D. (Univ of VT Medical Center) and Louis Landsberg, M.D. (Harvard Medical School)

Background:

Collaboration with clinical research groups studying endocrine regulation of body composition has been continuing over the past 10 years; they contribute expertise in thyroid, catecholamines and similar endocrine regulators, develop and staff the protocols through their own human use committees, obtain, house, feed and otherwise care for subjects and carry out all clinical and chemical assays; USARIEM staff obtains measurements of metabolism at rest or work at appropriate periods during the protocols and assess changes.

Progress:

Equipment for all measurements, as detailed in last year's report, has been obtained, and personnel have been identified and trained in its use. The work has been delayed by failure to recruit a principal investigator to direct the efforts at Phoenix; this has been resolved by the decision that Dr. Danforth will be released from his duties at the University of Vermont Medical Center as of December 1980 and will essentially move from his primary base of operations to Arizona temporarily in order to get the study running. The decision has also been reached that the first study to be done will involve evaluation of the responses of the Pima to infused norepinephrine and the modification of their responses by induction of cold acclimatization since Stock has recently suggested that a primary defect in non-shivering thermogenesis may be an important factor in failure of body weight regulation. Such a mechanism is in fact associated with obesity in the generic obese mouse.

Manuscripts on lipodystrophy have been published in the open literature and additional manuscripts are still being prepared.

(025)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OG 0711	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
80 01 31	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61101A	3A161101A91C	00	025
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code) (U)Development of Assessment of Biometerologic Variables and Their Influence on Health and Performance(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 007900 Occupational Medicine; C05900 Environmental Biology; 013400 Psychological; 016800 Toxicology; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	1.0	50
	CURRENT 81	0.5	25

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

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20. PERFORMING ORGANIZATION

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TELEPHONE: 955-2854

SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: ZISKIND, David DA

NAME: STOKES, James W., LTC, MC

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Biometerology; (U)Air Ions; (U)Humidity; (U)Environmental Health; (U)Environmental Comfort (U)Human Performance

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) An extensive literature on indicates that atmospheric phenomena besides temperature may produce medical and psychological symptoms. Notorious winds from deserts or mountain ranges where U.S. troops may be deployed are associated with malaise, upper respiratory and eye irritation, dyspnea, headache, impaired performance, depression, suicide, murder, accidents and absenteeism; these weather fronts involve a net excess of positive air ions which are hypothesized to trigger neuroendocrine secretion in sensitive individuals. Air ionization may account for geographical variability of acute mountain sickness at equivalent elevations. Positive air ions also reportedly cause symptoms in operators of electronics equipment in confined spaces such as Army personnal use. Tasks of critical military importance (vigilance, quick reaction and psychomotor coordinations) are reported especially sensitive. . The biological effects of air ions are probably modified by ambient humidity, temperature, barometric pressure, dust, ozone or other pollutants, accounting for some contradictory research results. These variables may also be important per se: e.g. relative humidities outside the narrow "comfort zone" effect subjective well-being and perhaps performance and health more than are explained by the thermodynamics.

24. (U) Potentially influential biometeorologic variables should be monitored, if not controlled, in USARIEM's laboratory and field studies of heat, cold and hypoxic (hypobaric) stress. USARIEM's environmental chambers permit systematic exploration of multiple biometeorologic variables related to USARIEM's primary mission areas. This work unit supports equipment procurement, characterization of the physical interactions of the variables in the experimental settings, and exploratory tests of behavioral and physiological effects in human volunteers and animal models.

25. (U) 79 10 - 80 09 Literature search and consultation with other laboratories was conducted. Equipment to generate air ions and to measure air ionization, barometric pressure, wet globe temperature and chemical pollutants was evaluated and purchased. Equipment to assess dust particles was borrowed. Measurements were taken in USARIEM environmental chambers under conditions to be used in future experiments. A protocol is undergoing human use review.

* Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	025 Development of Assessment of Biometerologic Variables and Their Influence on Health and Performance
Study Title:	Effects of Air Ionization on Human Mood and Performance
Investigators:	David Ziskind, MA, James B. Sampson, Ph.D., James W. Stokes, LTC(P), MC

Background:

An extensive literature in Biometeorology indicates that a number of atmospheric phenomena can influence health and efficiency besides those which directly impact on the thermodynamics or the blood oxygenation of the organism. Of special interest to the mission of USARIEM are the notorious winds from desert or mountain regions which since the late 19th century have been correlated with increased absenteeism, accident rates, murder, suicide, and hospital admissions for a variety of illnesses (1). Known regionally by different names (the hot-dry Chamsin or Sharav of the Middle East, Sirocco or Xlokk of the Mediterranean, Zonda of Argentina and Santa Ana of the S.W. United States; the warm-dry Foehn from the Alps and Chinook from the Rocky Mountains, the cold-dry Mistral of South France), these winds involve different combinations of temperature and humidity. More strikingly, the disturbances of mood and the migraine-like symptoms which affect an estimated 20% of a region's population often preceeds the arrival of the temperature/humidity change by 24-48 h.

The predominant theory for the syndrome described above is that the symptoms are caused by the static electrical charge of the air (which can move faster than the wind itself), specifically by a net excess of positive ions produced as electrons are "rubbed off" molecules of CO_2, O_2, N_2 when air masses flow across the barren rocks or sand (2,3). Evidence supports the hypothesis that inhalation of the positive ions triggers release of serotonin by the bronchial or alveolar cells into the blood stream of sensitive individuals (4,5). Note: claims that negative air ion generators improve subjective well-being and performance continue to be controversial.

The potential loss of operator efficiency in Army teams performing complex, critical functions (more than the relatively minor symptoms of headache, upper respiratory distress, nausea, etc.) make assessment and evaluation of this phenomenon by USARIEM important. At risk are not only troops deployed to desert regions or to south central Europe, but also those who work with electrical apparatus that produces positive air ions or in closed artificial environments which deplete negative air ions. Local positive ionization may also contribute to the marked variability of Acute Mountain Sickness in different high mountain ranges or even in different valleys at the same altitude. Temperature, humidity (or lack of it), barometric pressure, dust and air pollutants definitely influence the concentration, mobility (size) and biological activity of air ions, but the interactions of these variables have not been systematically evaluated. USARIEM's climatic chambers provide opportunity for pilot investigations to define the magnitude of the problem, to parameterize it, and to study various ways of minimizing adverse effects on critical military performance.

Progress:

The literature was reviewed. Equipment for generating and monitoring air ion concentration and mobility was evaluated and procured. Supplies for measuring contaminant gases were purchased, and a device for measuring dust particle concentration and size was borrowed from USAMRIID. This equipment is being calibrated in the climatic chambers under various conditions of temperature and humidity to assure the necessary experimental control over the physical interaction of the variables. Apparatus has also been assembled for measurement of galvanic skin response, to be used to screen test subjects for autonomic lability (presumed related to air ion sensitivity). Performance tests involving a range of psychomotor, cognitive and perceptual skills are being assembled.

The study protocol has been approved by the USARIEM Human Use Review Committee and is undergoing final review at OTSG. The experimental design will test volunteer subjects in comfortable and hot-dry or hot-humid conditions for durations of 4 h, during which they will also be exposed to positive, neutral and perhaps also negative ion concentrations. Performance efficiency and questionnaire self-reports of symptoms will be analyzed. A follow-up study will compare comfortable sea level conditions with 14,000 ft simulated altitude, low humidity.

On site measurements of ion concentrations, dust and pollutants will also be made during other USARIEM environmental chamber and Pikes Peak (4300m elevation) laboratory facility studies.

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(026)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OG 0705	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
80 01 3	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61101A	3A161101A91C	00	026
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U)Development of Capability to Assess Psychosocial and Physiological Indices During Performance

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

(22); 013400 Psychology; 016200 Stress Physiology; 005900 Environmental Biology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	1.0	54
	CURRENT 81	1.0	74

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: KOBRICK, John L., Ph.D. DA

NAME: BANDERET, Louis E., Ph.D.

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Electroencephalography; Evoked Cortical Potentials; (U)Cerebral Function; (U)Pupillometry

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Existing psychosocial and psychophysiological measures can be adapted to USARIEM studies to give insight into performance degradation under stress and to suggest means of prevention or treatment. Interaction Process Analysis (IPA) was originally developed by Bales to classify and quantify the social interaction of indivdiuals in groups. EEG sensory evoked potentials and cortical frequency spectra are used to provide indices of central nervous system activity and arousal.

24. (U) In consultation with laboratories using these techniques, evaluate existing methodologies and adapt them to USARIEM's special requirements, develop instrumentation and ADP capability, train personnel and conduct pilot tests.

25. (U) 79 10 - 80 09 IPA was modified to assess social communication among members of four 82d ABN Div artillery fire direction center teams (recorded on audio and video during laboratory sustained combat simulations conducted in FY '77 under 6.2 funding; the FDC performance data are reported under WU 055). Initial findings related changes in communication during lulls to the teams' performance and to eventual voluntary withdrawal from the experiment. Observed decreases in "positive" and/or increases in "negative" communication with time in sustained operations were reported at a NATO symposium on Motivation and Morale, Sep '80. Procedures, instrumentation and computer software were perfected to make IPA less time consuming and able to utilize less specialized personnel. As future IPA applications may involve Army teams in the field, expertise at the Navy's Pacific Missile Range was solicited for a feasibility test to modify a Medilog recorder to obtain 8 hours of voice and physiological data per cassettes from free moving subjects. Computer programs for EEG spectral analysis and evoked potential averaging were obtained from the Naval Sub Med Rsch Lab, and adapted to USARIEM's computers. Subjects were recorded under a variety of conditions to provide experience in data collection and analysis.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	026 Development of Capability to Assess Psychosocial and Physiological Indices During Performance
Study Title:	Interaction Process Analysis of FDC Teams in Simulated Sustained Combat
Investigators:	Louis E. Banderet, Ph.D. and James W. Stokes, LTC(P), MC

Background:

In Army combat teams, leadership style, social support and team cohesiveness are major determinants of performance, physiological responses to stress, coping strategies, and individual well-being, e.g. (1, 2). At USARIEM a multidisciplinary laboratory program was developed for assessing the interaction of operational efficiency, physiological, behavioral, and social variables in Army teams (3).

In 1977, four 82d Airborne Division fire direction center (FDC) teams each consisting of five male volunteers were tested under intense operational demands and sleep-depriving conditions in a laboratory simulation of their military functions (4, 5). Teams 1 & 4 were each advised they would undergo an 86 hours sustained operations challenge, a duration generally believed to exceed the capabilities of such teams under these conditions. Indeed, Team 1 withdrew voluntarily from the study after 48 hours and Team 4 after 45 hours, in part because they perceived that they were no longer functioning adequately. In contrast, Teams 2 & 3 were informed they would experience two 36-42 hours challenges separated by a 30-36 hours rest period, durations FDC teams had experienced previously in field exercises without incapacitation. Each team completed both challenges.

Except for the differences in trial durations, all four teams received the same scenario of operational demands, which was standardized so that similar events of differing complexity and urgency recurred every 6 hours throughout the sustained operations. Also prespecified in each 6 hours were two lulls, simply unannounced 12 minute intervals when no new operational demands were directed to the FDC, although message traffic irrelevant to the FDC continued on the simulated radio nets.

These studies (4-5) provided paradigms to quantify changes in social interaction in small Army teams during acute exposure to environmental stress and fatigue, and to determine if such changes were related to operational performance. Although work loads per 6 hours were equivalent for the teams studied, differences in prior experience, organizational style, and ultimately in final outcome, provided opportunities for evaluating the interplay of operational effectiveness and motivation and morale.

Progress:

Interaction Process Analysis (6) was modified to assess intra-team communications. Vocalizations from each team member during the lulls were transcribed from audio records and arrayed against a common-time axis. All utterances were divided into standard communication units (CU), i.e. sounds or words that conveyed a single thought, meaning or action. Standard communications in the processing, computation and transmission of firing data were identified and classified as Task SOP CU. All Other CU were each classified into 1 of Bales's 12 categories (6). For each CU, the sender and receiver were specified and all data were coded for automatic data processing. To describe the affective quality of each team's communications, each category 1, 2, or 3 CU (i.e. seems friendly, dramatizes, or agrees) was tabulated as a "positive" action. Each category 10, 11, or 12 CU (disagrees, shows tension, or seems unfriendly) was logged as a "negative" action. Procedural accuracy was insured by comparing data from two independent transcribers/scorers and resolving any discrepancies. Video records were viewed before scoring.

This report deals with the examination of positive and negative intra-team communications occurring during the lulls for Teams 1, 2, and 4. (Team 3 data are being analyzed). Initial findings from other analyses of communications, presented at the U. S. Army Science Conference, concerned changes in total, Task SOP, and All Other CU (5). These data are described in this annual report under WU 055 (DAOC 6121, page 461), but are relevent to this analysis. In brief, total communications declined by 40-50% with increasing hours of sustained operations in Teams 1, 2 & 4. During the lulls, Task SOP communications generally occurred when a team was behind in processing some of their operational demands (i.e., preplanning). With increasing unprocessed preplanning demands, the communications of Teams 1 and 4 became more task-oriented up to

24-30 hours of operations. Thereafter, Task SOP CU decreased in spite of increasing preplanning backlogs which eventually resulted in dramatic operational failures due to deterioration of timeliness and accuracy of missions which required advanced preparations (4). In contrast, Team 2 was, from the outset, more efficient at processing preplanned targets, and consequently seldom worked on task demands during the lulls.

Figure 1 shows the number of positive and negative interactions for each team with time. In Team 1 positive interactions decreased more than 80% after an initial peak at 6-12 hours. Negative interactions also decreased and after 18 hours almost equaled the positive interactions. After 48 hours in the simulation (7 a.m.), one enlisted chart operator resolved to quit. When the team was unsuccessful into persuading him to stay, the officer decided that the team should leave together. We speculate that the progressive loss of accustomed comradeship and social support in the team may have contributed to the chart operator's feeling that the team goal no longer justified his personal discomfort.

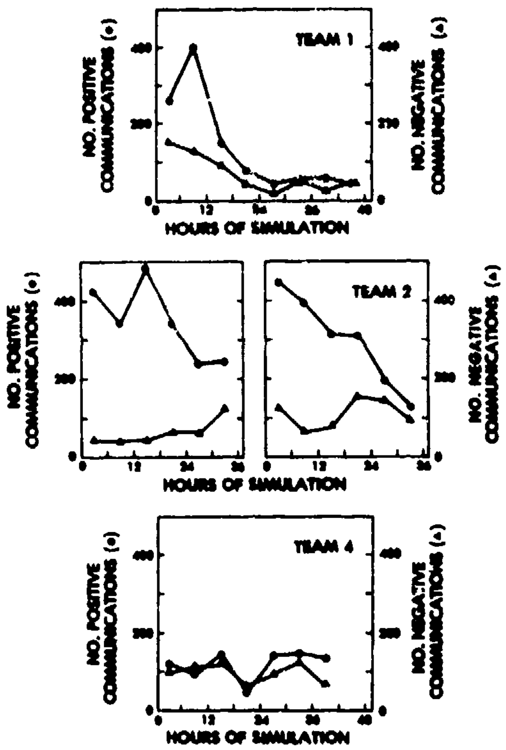

Figure 1. Number of positive and negative communications for Teams 1, 2, & 4 with hours in the simulation. Solid circles show positive communications; solid triangles, negative communications. Only CU's classified in Bales's categories 1-3 (positive) and 10-12 (negative) were considered in these data.

In Team 2, positive interactions decreased more than 50% from initial values in both challenges. The decrease was more marked during the second 38 hours challenge. Negative interactions increased from a low initial value in the first challenge, and in the second challenge exceeded the first challenge maximum after 18 hours. Interestingly, at about 27 hours in the second challenge, when the negative CU almost equaled the positive, enlisted members of Team 2 became so discouraged that they questioned the team's ability to finish the challenge. The officer successfully encouraged them to persist by reminding them that they had experienced 36 hours before and could do it again. Team 2's operational performance had showed significant deteriorations after 24 hours in the second challenge, changes that were not evident in the first challenge. (4, 5) Changes in the number of positive and negative communications after 24 hours of the second challenge were more extreme than even after 36 hours of challenge 1. One might speculate if Team 2's positive and negative communication trends and self doubts were the "causes" or the "effects" of the deteriorating performance observed during the final hours of Team 2's second challenge. The time course of the performance changes (4,5) favors the view that the communication changes were responses to earlier performance deterioration. However, the doubts about the team's ability to continue appear to have resulted from altered perceptions of the team and especially the NCO. The role of the communications and affective changes cited in influencing such individual or team appraisals, attitudes and morale should not be underestimated.

In contrast to Teams 1 & 2, the number of positive and negative interactions in Team 4 were comparable and remained so through 42 hours. Team 4 was the newest team; three of its members had just completed artillery schooling. As indicated previously, this team was substantially involved with Task SOP communications during the lulls, but were progressively unable to do this after 30 hours as the experienced lieutenant became fatigued and less able to supervise and direct. Team 4 terminated after 45 hours (at 4 a.m.) when the team's sergeant advised the lieutenant that the inexperienced enlisted men had reached their limits. The decision did not involve a group consensus or any one man's exercise of his right to withdraw, but rather was a decision of the leaders that the team could no longer function adequately.

It might be argued that the observed decreases in number of positive communications in Teams 1 & 2 are due only to the decreases in the number of All Other communications with time (5). That is, this view suggests the proportion of the positive interactions did not change with time; rather, the number of positive interactions decreased proportionately as All Other communications decreased.

To examine this posibility, positive and negative communications are shown as percentages of All Other communications for each 6 hours in Table 1. As can be observed, the almost two-fold decrease in percentage of positive communications from maximum clearly rules out the former possibility. Early in the simulation the percentage of positive communications in Teams 1 & 2, (i.e. 35-59%) was much greater than it was from 24-36 hours. Table 1 and Figure 1 show that both the proportion and number of positive communications decreased.

TABLE 1

Percentages of positive and negative communications with hours in the simulation for Teams 1, 2, 4. Values arrayed are 100 times the ratio of positive (or negative) CU to All Other CU.

HOURS IN SIMULATION	TEAM 1		TEAM 2				TEAM 4	
	CHALLENGE 1		CHALLENGE 1		CHALLENGE 2		CHALLENGE 1	
	% "+"	% "–"	% "+"	% "–"	% "+"	% "–"	% "+"	% "–"
0 - 6	35	20	56	6	46	12	23	20
6 - 12	48	16	42	5	59	10	19	24
12 - 18	31	18	55	5	46	11	26	21
18 - 24	20	11	44	9	38	19	18	24
24 - 30	21	9	44	12	27	20	30	20
30 - 36	23	28	40	20	26	19	30	26
36 - 42	20	9	—	—	—	—	29	15
42 - 48	20	20	—	—	—	—	—†	—†

NOTE: †TEAM 4 WITHDREW AFTER 45 H IN THE SIMULATION. THEIR WITHDRAWAL OCCURRED DURING THE FIRST LULL.

The decrease in the percentage of positive communications appears largely offset by increased CU in Bales's categories 4 thru 9 and a small increase in the proportion of negative communications in Team [illegible]. In Team 4 the proportion of positive communications was slightly greater after 24 hours.

Further IPA is underway to evaluate the communications patterns of the individuals within each team. This may provide objective assessment of changing social roles (e.g. motivator, comic, tension reliever, critic) and of such elusive, but potentially significant, contributors to morale as humor.

These initial IPA results, demonstrating relationships to observed changes in operational efficiency (5) and motivation/morale in FDC teams during simulated sustained operations, suggest that the method may be useful in other settings, e.g. for study of combat vehicle crews or command/staff groups. Accordingly we are implementing procedures and techniques which will reduce cost, personnel, and time requirements associated with future analyses. These efforts are concentrated in three principal areas: 1) a more efficient transfer of speech and time information from audio tapes into the computer, 2) verbal transcripts for all team members arrayed in a computer printout along a common-time axis, and 3) small portable "audio" recorders to collect speech from Army personnel in the field.

Much has been done to optimize the transfer of verbal and time information into automated data processing equipment. Clerk typists now use transcribing machines to generate the verbal transcripts and associated real-time values which describe when speech bursts occurred. To eliminate "waiting time" when personnel generate verbal transcripts from audio tapes, they use compressed recordings which eliminate any original tape portions where speech was absent for ≥ 7 seconds. The time-code information is preserved with the associated speech information, but on the "compressed" recordings the speech bursts are nearly continuous. The verbal and time information are either card punched for subsequent entry into the computer or entered directly from a computer terminal.

A COBOL program was developed for this application. After each individual's speech and time information are entered in the computer, the team's communications are arrayed and written out on the line printer. The time savings and other advantages of using the computer to arrange the verbal information for each team member against a common-time axis and to produce multiple copies are substantial compared to the manual methods we used previously.

We feel the best way to collect speech samples from Army teams during field experiments and to preserve the temporal sequencing of their communications is to outfit each subject with a portable recorder with two or more channels. This will allow independent recording of speech and time code information from free-moving individuals even in noisy conditions. Subsequently, verbal transcripts from different team members can be arrayed in time on a single printout and the temporal sequencing of a group's verbal interactions will be preserved. We are currently exploring the feasibility of combining the existing state-of-the-art from 2 to 3 separate commercial product areas to yield a small, $\geq$ 2 channel, portable "audio" recorder. Tape transport speed would be slowed to permit 480 minutes of recording on one side of a normal C-120 cassette. It appears the recorder will have sufficient frequency response so that during play back, with amplification of certain frequencies, speech will be intelligible. If this device proves feasible, it will be a useful tool for the study of Army teams or other groups in their natural environments.

The above refinements would reduce the cost, personnel, and time requirements associated with IPA. More optimal data encoding and reduction techniques will yield more rapid data analyses and permit analysis of more information than feasible previously. The new equipment would permit collection of speech with time code information from Army teams during selected, controlled field experiments or training exercises in extreme environments.

Presentation:

Banderet, L. E. and J. W. Stokes. Interaction process analysis of FDC teams in simulated, sustained combat. NATO Symposium on Motivation and Morale, Brussels, Belgium, September 1980.

Publication:

Banderet, L. E. and J. W. Stokes. Interaction process analysis of FDC teams in simulated sustained combat. In Proceedings, NATO Symposium on Motivation and Morale. (In press). Brussels, Belgium, 1980.

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2. Bourne, P. G. The psychology and physiology of stress (Vietnam). Academic Press, New York, 1969.

3. Stokes, J. W., L. E. Banderet, R. P. Francesconi, A. Cymerman and J. B. Sampson. The Field Artillery Fire Direction Center as a laboratory and field stress-performance model: I Position paper; II Progress towards an experimental model. In The Role of The Clinical Laboratory in Aerospace Medicine, AGARD Publication AGARD-CP-180, A10-1 to A10-10, 1975.

4. Banderet, L. E., J. W. Stokes, R. Francesconi, D. M. Kowal and P. Naitoh. Artillery teams in simulated sustained combat: performance and other measures. In L. C. Johnson, D. I. Tepas, W. P. Colquhoun, M. J. Coligan (Eds.). The 24-Hour Workday. A Symposium on variations in work-sleep schedules. New York: Spectrum Publishing Inc. (In Press), 1981.

5. Banderet, L. E., J. W. Stokes, R. Francesconi and D. M. Kowal. Simulated, sustained-combat operations in the Field Artillery Fire Direction Center (FDC): A model for evaluating biomedical indices. Proceedings, Army Science Conference, West Point, NY. (In press), 1980.

6. Bales, R. F. Personality and interpersonal behavior. Holt, Rinehart & Winston, Inc., New York, 1970.

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	026 Development of Capability to Assess Psychosocial and Physiological Indices During Performance
Study Title:	Development of Methodology for the Application of Electroencephalographic and Sensory Response Measurements to the Investigation of Individual Differences in Military Performance
Investigators:	John L. Kobrick, Ph.D. and James W. Stokes, LTC(P), MC

Background:

The purpose of this project is to investigate the feasibility of using indices of central nervous system (CNS) response to illuminate the large differences in performance ability between individuals engaged in important military tasks, such as artillery forward observation, surveillance, and watchkeeping. Other objectives are to discriminate critical moments in performance from neutral situations within the same individuals through differences in CNS response, and to investigate change in CNS efficiency in general due to exposure to extreme natural environments, physical fatigue and sustained operations (perhaps compounded with pharmacologic defenses against chemical warfare agents). The ability to relate directly changes in indices of CNS activity to ongoing critical military task performance would provide many advantages perhaps for actual tactical operations. Demonstrating changes in CNS response can lead to more fundamental and theoretically significant explanations of the influence of environmental stress and operationally induced fatigue on military performance, as compared to the documentation of performance impairments alone. Those stress-sensitive CNS indicators which show satisfactory reproducibility may be used to build models of human performance under stress; findings from these models could be generalized to other tasks to predict impending action of special agents (e.g. antidote drugs, toxic substances) on performance at a much more fundamental level of effect than can be accomplished through empirical performance measurement alone.

Progress:

The primary objective of this project has been to evaluate and adapt the developed analysis programs and significant indices already derived by accomplished research in this field. The purpose is to determine whether the effects of environmental stress and sustained operations can be observed as resultant changes in CNS response.

Several other laboratories, both military and civilian, have successfully identified a variety of CNS response indices which show substantial and systematic changes directly associated with changes in operator performance and/or changes in task characteristics at the time. These are principally derived from electroencephalography (EEG), or from a category of more recent interest, sensory evoked responses (SER). Several reliable and sensitive indices and electrode locations have been used, and a number of new computer-oriented mathematical techniques based on Fourier transform analysis have been developed. These efforts focus on overall CNS output during selected epochs of performance, rather than on a search for isolated clinical signs.

From the literature on task-related EEG and SER changes and on computer analytical techniques for EEG records, several indices of potential significance have been identified for investigation at USARIEM: 1) ratio of temporal-parietal EEG activity, principally in the alpha range (1); 2) right-left hemisphere alpha dominance in verbal and motor tasks (6); 3) individual differences in lateral dominance of alpha output as related to task content (2); 4) lateral alpha asymmetry as related to reaction time for verbal and motor tasks; 5) SER component differences for critical as compared to innocuous visual and auditory signals.

A group of computer programs for spectral density function analysis of EEG records were acquired from the Naval Medical Submarine Research Laboratory, Groton, CT, and were successfully modified to operate on USARIEM DECLAB 11/03 and 11/40 computers. These programs are now operational, and a data collection and analysis system has been developed to acquire EEG records from performing subjects via magnetic tape for subsequent processing by computer. The DECLAB 11/03 has also been modified and equipped with two Schmitt-trigger units to operate as a signal averager for use in SER studies.

Another CNS-mediated response of potential theoretical as well as practical interest to military performance is the visual accommodative response at low illumination levels, such as would be encountered in night operations. Under optimum conditions, objects can normally be focused over a wide range of distances. However, at low illumination or when the stimulus is degraded in quality, the observer characteristically accommodates to an intermediate distance position, called the dark focus. The accuracy of steady-state accommodation is highly dependent on the observer's characteristic dark focus, or neutral state of accommodation. The dark focus cannot be predicted from an individual's normal daylight refraction, and varies widely between individuals, but is very stable over repeated testing.

The accommodative mechanism is normally accomplished through the ciliary muscle acting on the lens to change its refractive index. The dark focus is presumed to be the result of a neutral state of opposing innervations of the ciliary muscle by the two sub-divisions of the autonomic nervous system. Since autonomic activity has long been known to be involved in exposure to stress (Selye's GAS syndrome (5), for example), one might reasonably expect the accommodative response to provide an indication of the relative balance of central sympathetic and parasympathetic tone. Also, paralysis of accommodation is an effect of atropine and some other drugs used as antidotes for chemical warfare agents; direct measurement of accommodation may be a sensitive means of monitoring drug action in studies of these antidotes.

A recently developed vernier optometer makes simple and extremely accurate measurements of accommodation without altering the normal accommodative response (6). A functional version of this device has been constructed at USARIEM, and will be employed in an upcoming study of the effects of levels of hypoxia on night vision to explore possible relationships between accommodation and general visual capability at low illumination levels.

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7. Tucker, D. M. Right hemisphere activation during stress. Neuropsychologica, 15:697-699, 1977.

(81027)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6127	79 05 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	H. TERMINATED	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	027
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Temperature and Sweat Production during Eccentric Work (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physilogy; 016200 Stress Physiology; 005900 Environmental Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 10	70 09	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	1.0	15
	CURRENT 80	0.0	0

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFILED, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* VOGEL, James A., Ph.D.

TELEPHONE: 955-2868

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: KNUTTGEN, Howard G., Ph.D.

NAME: 955-2800 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Eccentric Work; (U)negative Work; (U)Sweating Rate of Thermal Regulation

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Eccentric exercise is a situation where the muscle contracts to resist stretching or lengthening of the muscle as opposed to shortening of the muscle in concentric or positive exercise. Preliminary observations have indicated that sweat production is inordinately high during eccentric (negative) exercise as compared to standard concentric (positive) exercise. This high sweat trate appeared to diminish with eccentric training but returned to the high rate promptly after cessation of training. Temperature regulation during eccentric work has not been described. Core and skin temperature responses to eccentric work and their relation to these sweat rate observations have not been previously studied.

24. (U) The observations concerning high sweat rates will be confirmed on subjects performing eccentric exercise on a motor driver bicycle ergometer. Skin and core temperatures will be recorded and compared to standard concentric exercise. If eccentric exercise is found to ellicit a temperature regulating response different from concentric work, training will be evaluated as a modifier.

25. (U) 78 10 - 79 09 Data collection for this study has been completed. Preliminary analysis of the data indicates that metabolic heat production is increased in eccentric exercise above that which occurs in concentric exercise. No new protocols are planned for this reasearch and it is therefore terminated.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	027 In Vivo Effect of 2,3-Dephosphoglycerate on Factor VIII Procoagulant and Factor VIII von Willebrand Activities
Investigators:	John Gadarowski, CPT, MSC, Ph.D. and Murray P. Hamlet, Ph.D.

Background:

The purpose of this project was to determine if there was in rats an in vivo increase in both Factor VIII procoagulant and Factor VIII von Willebrand activities after the intravenous injection of 3,3-diphosphoglycerate.

Progress:

The reason why this project was considered was that after frostbite, I had observed hemolysis and an increase in Factor VIII procoagulant activity. Since hemolysis causes the release of 2,3-diphosphoglycerate (2,3 DPG) from the erythrocytes into the blood and since it is known that this chemical causes an increase in vivo of Factor VIII procoagulant activity, I wanted to determine if 2,3 DPG also was able to cause in increase in Factor VIII von Willebranch activity. In frostbite injury there could be an increase both in Factor VIII procoagulant activity, which is involved in blood coagulation, and in Factor VIII von Willebrand activity, which is involved in hemostatic plug formation.

A protocol was written after a two week review of the pertinent literature. The USARIEM Animal Use Committee reviewed this protocol and ruled that the project could not be done because it was believed to be militarily irrelevant. Due to its ruling, work on the project has been terminated indefinitely. Of the $1000 spent on expendable items for this project, approximately 70% of the items are being used on another project.

(027)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OG 0714	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	H. TERMINATED	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61101A	3A161101A91C	00	027
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)* (U) In Vivo Effect of 2,3-Diphosphoglycerate on Factor VIII Procoagulant and Factor VIII von Willebrand Activities (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

002300 Biochemistry; 012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	0.2	16
	CURRENT 81	0.0	00

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: PEARLMAN, ELIOT J., LTC, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* GADAROWSKI, John, Ph.D., CPT, MSC

TELEPHONE: 955-2868

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HAMLET, Murray P., D.V.M.

NAME: DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)2,3-Diphosphoglycerate; (U)Factor VIII Procoagulant Activity; (U)Factor VIII von Willebrand Activity; (U)Hemeostasis

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The purpose of this experiment is to determine if there is in rats an in vivo increase in both factor VIII procoagulant and von Willebrand activities after injection of 2,3-Diphosphoglycerate.

24. (U) Male Sprague Dawley rats, weighing 300-400 g, will be used in this experiment. The rats will be divided into the following groups: (a) 5 control non-injected rats, (b) 10 isotonic saline injected rats, and (c) 10 2,3-Diphosphoglycerate injected rats. All injections at 1.0 ml volume will be done through the caudal vein. Blood will be withdrawn 20 hr post injection by a cardiac puncture using a disposable plastic syringe. The rats will be anesthetized with ether during injection and blood sampling. After blood sampling all rats will be euthanized by an overdose of ether. 2,3-Diphosphoglycerate will be dissolved in isotonic saline at a concentration of 4uM/ml. 1.0 ml of 2,3-Diphosphoglycerate or isotonic saline will be injected. Platelet poor plasma will be used. It will be obtained by centrifuging citrated blood in a plastic test tube at 4°C for 15 minutes at 5000 rev./min. Factor VIII procoagulant activity will be determined and Factor VIII von Willebrand activity will be assayed.

25. (U) 79 10 - 80 09 A protocol was written after a two week review of the pertinent literature. The USARIEM Animal Use Committee reviewed the protocol and ruled against proceeding with the project because it believed that the project was militarily irrelevant. Due to its ruling, work on the project has been terminated indefinitely.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

(001)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OA 6142	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☑ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61102A	3M161102BS10	CA	001
b. FORMER	6.11.02.A	3E161102BS08	00	001
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code) (U)Development and Characterization of Models of Cold Injury and Hypothermia (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 002300 Biochemistry; 005900 Environmental Biology; 012900 Physiology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	3.0	99
	CURRENT 81	3.0	94

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

ADDRESS: Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: PEARLMAN, ELIOT J., LTC, MC

TELEPHONE: 955-2811

21. GENERAL USE

Foreign Intelligence Not Considered

20. PERFORMING ORGANIZATION

NAME: USA RSCH INST OF ENV MED

ADDRESS: Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME: HAMLET, Murray P., D.V.M.

TELEPHONE: 955-2865

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: ROBERTS, Donald E., Ph.D.

NAME: DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U)Frostbite; (U)Thermoregulation; (U) Hypothermia

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Study :tors involved in frostbite and other non-freezing injuries in both animals and man. Provide a rational basis for treatment and prevention of those injuries sustained by military operations.

24. (U) A dog model will be used to study the physiological effects of hypothermia and to examine problems encountered during rewarming by various means.

25. (U) 79 10 - 80 09 The paper relating dehydration to finger cooling in air has been re-submitted for publication. The paper involving physical work while breathing -40° air has been accepted for publication. One study on airway rewarming severe hypothermic dogs has been completed but not published. The study basic fluid dynamics during hypothermia is continuing with five runs completed.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BD08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	001 The Development and Characterization of Models of Cold Injury and Hypothermia
Study Title:	An Evaluation of Various Methods of Rewarming Hypothermic Victims
Investigators:	Donald E. Roberts, Ph.D., John Patton, Ph.D., J. Grant Barr, CPT, MSC, Ph.D.

Background:

Accidental hypothermia, either due to exposure or water immersion is a continuing problem for both the military and civilian communities. External methods of rewarming are more widely used than internal methods, but there are certain problems with either method. External methods often produce an afterdrop in core temperature and subsequent cardiovascular embarrassment (1,2,3,4,5,6). Internal rewarming techniques are better but require better medical facilities for treatment (7,9,12,13). Newer methods are being tried, i.e. airway rewarming, that tend to warm centrally and are non-invasive (3,8,10,11,14). Other techniques being advocated are the use of I.V. fluids to help stabilize the victim prior to rewarming.

Progress:

This work unit is involved with determining certain physiological parameters during rewarming from hypothermia. This involves the determination of heart rate, blood pressure, central venous pressure, cardiac contractility, core and surface temperatures, blood and urine electrolyte changes, blood gas changes, and changes in plasma volume.

The study design is to obtain data on "control" animals which are rewarmed by an external method and compare any other method of rewarming to this method. Our standard of rewarming is the use of an external circulating fluid blanket which is a reversal of the cooling method. This type of approach can also be used to assess the efficacy of using fluids before rewarming is started.

The animal model used is the dog. The dog is normal except that some studies call for the spleen to be removed (decrease RBC storage) and for an implanted pressure transducer to be placed in the left ventricle. All blood and urine measurements are made by standard tests.

We have completed the first study in this area. We have compared the rewarming of dogs by external only to rewarming by external plus airway rewarming. These animals were cooled to 28°C and rewarming was begun. The inspired air was warmed to 44°C and humidified. Figure 1 shows the rewarming curves for the cardiac temperature for these two groups of animals. The curves are not significantly different from each other. The only real difference was found in the blood gas levels. The airway rewarming pushed the blood oxygen level to a more normal level in a shorter time. This data is shown in Figure 2 as a percent change from the precooling level (base) for both groups of animals. This group of animals with airway rewarming showed a greater incidence of alteration in EKG wave forms than did the external rewarmed animals.

We are now in the process of cooling animals with the spleen removed (to minimize hematocrit changes as shown in Figure 2) and with a pressure transducer installed in the left ventricle to assess cardiac contractility. We are interested in obtaining basic cardiovascular data on hypothermic animals and also in assessing the impact on a cold heart of administering I.V. fluids. We have completed three animals and we are in the process of preparing nine more animals.

The rationale for this study is to examine the effect of increased fluid pressure (I.V. fluids) on a marginal (cold) heart. Figure 2 shows the persistent changes in cardiovascular function induced by hypothermia, and this study will answer questions on increased stress to the cardiovascular system.

Presentations:

1. D. E. Roberts, J. J. Berberich, and D. W. Kerr. Circadian effects on peripheral temperature response. Federation of American Societies for Experimental Biology, Anaheim, CA, April 1980.

2. D. E. Roberts, J. J. Berberich, and D. W. Kerr. The effects of aerobic fitness training on response to cold exposure. American College of Sports Medicine Annual Meeting, May 1980.

Publication:

J. J. Jaeger, E. C. Deal, D. E. Roberts, and E. R. McFadden. Cold air inhalation, esophageal temperature and lung function in exercising humans. Medicine and Science in Sports. (In press).

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1. Blair, E. Clinical Hypothermia, McGraw Hill, pp. 38, 42-43, 80-82, 210, New York, 1964.

2. Blair, E., A. V. Montgomery, and H. Swan. Posthypothermic circulatory failure. I. Physiologic observations on the circulation. Circulation 13:909-915, 1956.

3. Collis, M. L., A. M. Steinman, and R. D. Chaney. Accidental hypothermia: An experimental study of practical rewarming methods. Aviat. Space Environ. Med. 48:625-632, 1977.

4. D'Amato, H. E., S. Kronhein, and B. G. Cavino. Cardiovascular function in the dog rewarmed rapidly and slowly from deep hypothermia. Am. J. Physiol. 198:333-335, 1960.

5. Fedor, E. J., B. Fisher, and S. H. Lee. Rewarming following hypothermia of two to twelve hours. I. Cardiovascular effects. Ann. Surg. 147:515-530, 1958.

6. Fernandes, J. P., R. A. O'Rourke, and G. A. Ewy. Rapid external rewarming in accidental hypothermia. J. A. M. A. 212:153-156, 1970.

7. Gregory, R. T., J. F. Patton, and T. T. McFadden. Cardiovascular effects of arteriovenous shunt rewarming following experimental hypothermia. Surgery 73:561-571, 1973.

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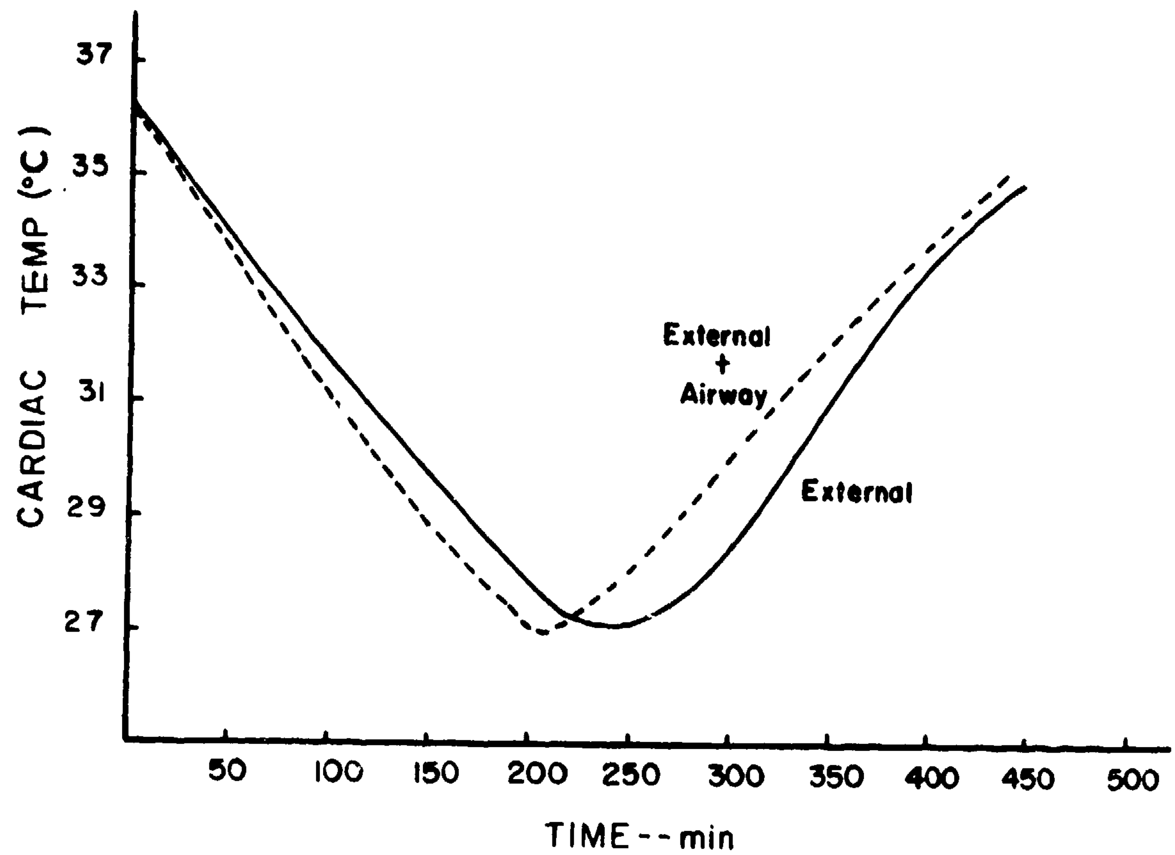

Figure 1. Cooling and rewarming curves for the average of two groups of five animals.

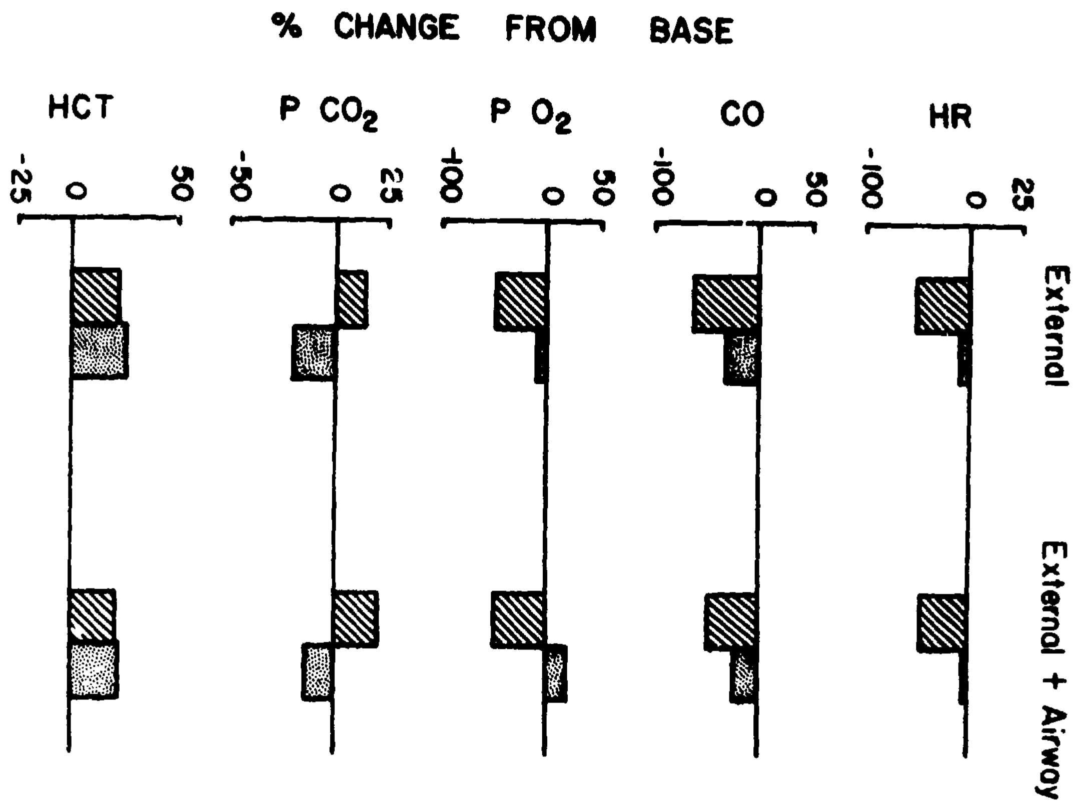

Figure 2. Average physiological data calculated as a percent change from precooling level.

(002)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OA 6144	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	R.CORRECTION	U	U	NA	NC	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61102A	3M161102BS10	CA	002
b. FORMER	6.11.02.A	3E161102BS08	00	002
c. XXXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)* (U)Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology; 005900 Environmental Biology; 012600 Pharmacology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:*
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	7.0	165
	CURRENT 81	7.0	157

19. RESPONSIBLE DOD ORGANIZATION
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RESPONSIBLE INDIVIDUAL
NAME: PEARLMAN, ELIOT J., LTC, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* CYMERMAN, Allen, Ph.D.
TELEPHONE: 955-2885
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: YOUNG, Andrew J., Ph.D., CPT, MSC
NAME: MAHER, JOHN T., Ph.D., DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Acute Mountain Sickness; (U)Pulmonary Arterial Hypertension; (U)Spontaneous Motor Activity; (U) Animal Models

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Acute mountain sickness and high altitude pulmonary edema are debilitating disorders associated with the lowered oxygen present at high terrestrial elevations. Many of the physiological and biochemical parameters of these disorders cannot be studied in man due to the invasive nature of the measurements. The purpose of this work unit is to develop appropriate animal models to enable: (1) the elucidation of the physiological and biochemical adaptations which occur in response to the stress of high terrestrial elevations; and (2) the identification of new approaches for improving military effectiveness at high terrestrial elevations.

24. (U) Models will be developed and/or used for investigating: (1) physiological and biochemical responses to altitude; (2) control mechanisms operative in these responses; (3) etiology and symptomatology of acute mountain sickness and high altitude pulmonary edema and; (4) related functional deficits and disabilities.

25. (U) 79 10 - 80 09 Preliminary studies have been carried out in unanesthetized, intact goats to assess the effectiveness to phenytoin sodium (Dilantin®) as a possible therapeutic agent in the reduction of altitude-induced pulmonary arterial hypertension; (2) In response to a hypoxic environment, rats were found to exhibit physiological and behavioral changes which resemble acute mountain sickness in man.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	002 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations
Study Title:	Phenytoin as a Possible Therapeutic Agent in the Reduction of High Altitude Pulmonary Arterial Hypertension
Investigators:	Walter H. Inge, Ph.D., Richard L. Burse, Sc.D., John C. Donovan, CPT, VC, and John T. Maher, Ph.D.

Background:

Pulmonary arterial hypertension is an invariable result of hypoxic exposure in a wide variety of animals, including man (1,5,7,8,12,14). This pulmonary hypertension is sometimes accompanied by an increase in pulmonary blood volume and the occurrence of pulmonary edema (9,11,13,15). It is probable that a reduction in the hypertensive response of the pulmonary vasculature to hypoxia would lessen the chances of the potentially fatal pulmonary edema suffered by some individuals at high altitude. Any prophylactic or therapeutic method which would reduce these adverse effects of high altitude would have obvious value in assisting the soldier to accomplish his mission at high altitudes.

Among the drugs which have been proposed for prophylaxis and treatment of hypoxic pulmonary hypertension are antihistamines, steroids, acetazolamide and other diuretics, and prostaglandin synthesis inhibitors (3,4). While none of these drugs has conclusively demonstrated benefits in reducing hypoxic pulmonary hypertension, acetazolamide and other carbonic anhydrase inhibitors have been reported to ameliorate some of the symptoms of mountain sickness (2,6).

Dilantin® (phenytoin sodium) has been reported to decrease the pulmonary hypertensive response to hypoxia in anesthetized, thoracotomized, bronchially cannulated dogs (10). No data are available on this drug's effect on the pulmonary vasculature of intact, conscious animals. If Dilantin proves to be effective in reducing hypoxic pulmonary hypertension in the conscious, intact animal, it might also prove to be of prophylactic value in humans exposed to high altitudes, not only in the prevention of pulmonary hypertension, but also in avoiding the pulmonary edema which may accompany the hypertension. A protocol was designed for the present study in order to test the value of Dilantin at altitude. In a cross-over experiment, eight goats will be instrumented in order to measure systemic and pulmonic blood pressures, cardiac output, ventilatory rates and volumes and expired gas compositions. These parameters will be measured at sea level and at a simulated altitude of 4600 meters, comparing goats primed with Dilantin with those given a placebo.

Progress:

During the Third Quarter FY80, the protocol was approved. A sea level pilot study involving one goat was conducted in order to check out equipment used to record hemodynamic and ventilatory parameters, and to accomplish respiratory gas analyses. Pulmonary arterial pressures and wedge pressures were obtained successfully. The results of this pilot study suggested several minor changes in technique in the measurement of ventilation and expired gases. An attempt during this period to establish a priming dose regimen for Dilantin was not successful. A repetition of this phase of the pilot study was begun in September 1980 to determine the maximum safe blood level of the drug that can be established and consistently maintained. Once this has been determined, the full-scale study at sea level and at a simulated altitude of 4,600 meters will be initiated.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 002 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations

Study Title: Effect of Altitude on the Body Fluid Spaces and Behavior of the Rat

Investigator: Allen Cymerman, Ph.D.

Background:

Acute mountain sickness (AMS) is a self-limiting debilitating illness which has the capacity to demoralize and incapacitate troops exposed to high altitude. In order to study the basic physiological mechanisms and investigate possible regimens for prevention or amelioration of this illness, an animal model would be extremely useful. Our efforts have been directed toward determining the appropriateness of the rat as a model of AMS and have involved the measurement of altitude-induced changes in fluid compartments. We initially found increases in hematocrit, hemoglobin and the water content of several organs within 2 days of exposure to 5486 meters simulated altitude. In addition, there was a marked variability in relative fluid gain of different organs with brain and lung showing the largest change. Because wet-dry weight ratios do not indicate intra- and extracellular fluid shifts, an attempt was made to use two radioisotopes, $^{35}SO_4$ and ^{3}H, which distribute to appropriate fluid compartments, to measure the time course of any fluid shifts. This proved to be unfeasible in the rat. Instead, experiments were designed to quantify the magnitude of the temporal changes in behavior of the rat during exposure to different altitudes with the assumption that changes in activity would be indicative of the presence of AMS if these changes could be shown to be dependent upon elevation and duration of exposure.

Progress:

A software program, in conjunction with an on-line computer, has been written to assess the spontaneous motor activity of free-roaming rats using changes in the capacitance field of an animal activity monitor.

Several experiments were performed at different simulated altitudes. In each experiment normal adult rats were placed in modified plexiglass cages atop standardized activity monitors and data collected for several days prior to decompression to either 3660, 4573, 5488 or 6400 meters (12,000, 15,000, 18,000 or 21,000 ft), respectively. Altitude exposures usually lasted 2.5 days, except at 6400 meters where exposure lasted 4.5 days. Light and dark cycles were maintained at 0600-1800 hrs and 1800-0600 hrs, respectively. Figure 1 illustrates the diurnal cycles and levels of activity observed at sea level (A) and at altitudes up to 6,400 meters (B-E). At sea level (A) 24 hours is apparently required for the animals to adapt to their new environment after which a normal diurnal cycle and activity level is established. The cyclicity and activity level are still evident with exposure to 3660 meters (12,000 ft) (B). However, at 4573 meters (15,000 ft) (C), although a cyclicity is still visible, the level of activity is markedly reduced. At 5488 meters (18,000 feet) (D), cyclicity and activity are completely abolished. Graph E represents the highest altitude tested and the longest exposure time (4.5 days). Activity and periodicity are still depressed but there is an indication that activity level is beginning to recover after 3 days.

Numerical analysis of these results is ongoing but it appears that activity and periodicity are altitude dependent with readily observable changes occurring between 12,000 and 15,000 ft. It also appears that a normal activity level can be reestablished after 4 days even at 6400 meters. Thus, our present results indicate that the spontaneous motor activity of the rat may be used as an index of altitude acclimatization.

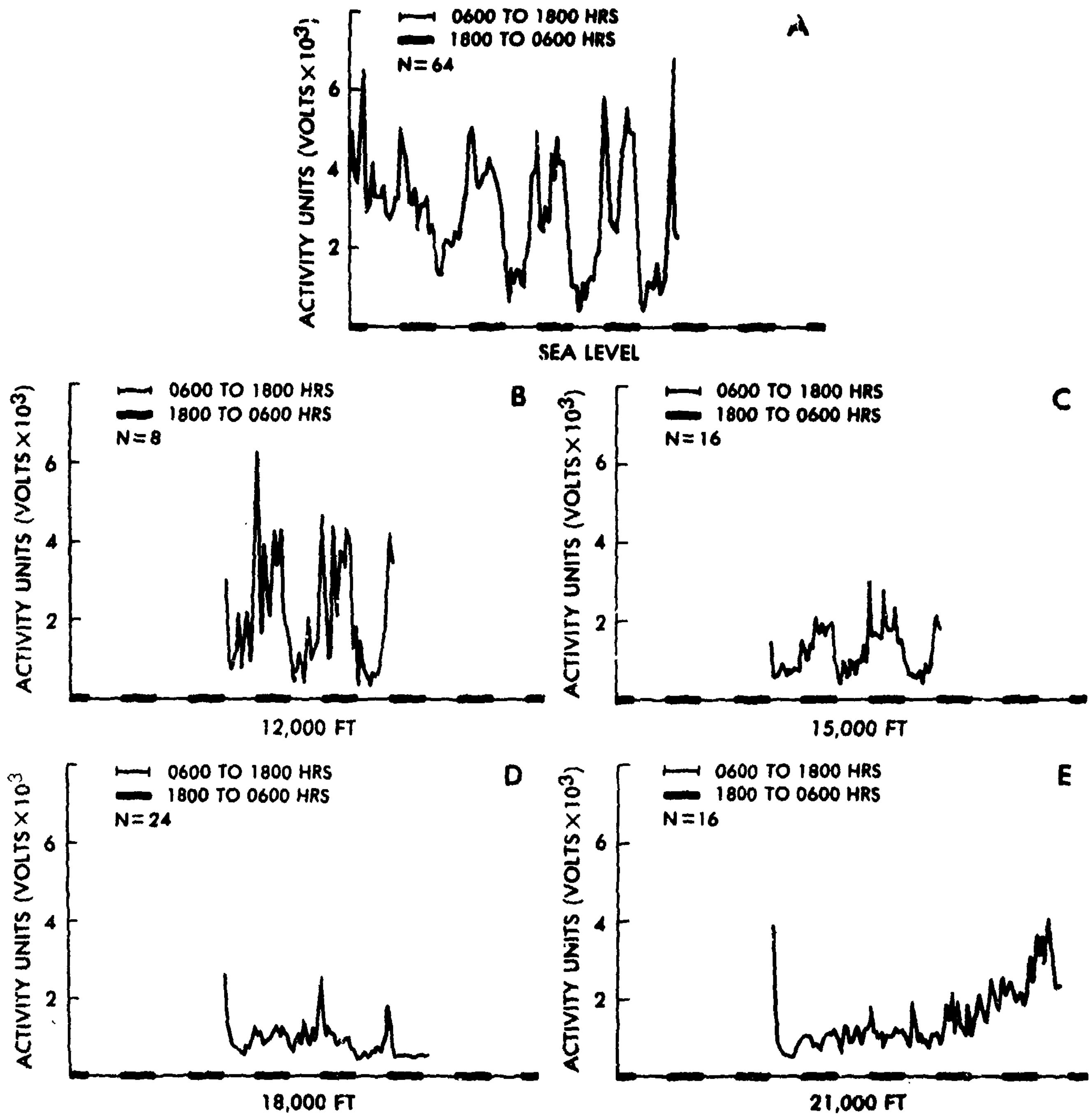

Figure 1. Effect of various simulated altitudes on the free-roaming spontaneous motor activity of the rat.

(005)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OC 6145	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
80 01 31	R.CORRECTION	U	U		NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61102A	3M161102BS10	00	005
b. FORMER	6.11.02.A	3E161102BS08	00	005
c. XXXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)

(U) Models of Heat Disabilities: Preventive Measures (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

016200 Stress Physiology; 005900 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	9.0	367
	CURRENT 81	8.0	333

19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME: MAGER, Milton, Ph.D.

TELEPHONE: 955-2871

SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: FRANCESCONI, Ralph P., Ph.D.

NAME: HUBBARD, Roger, Ph.D. DA

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Heat Stress; (U)Heat Disabilities; (U)Body Temperature; (U)Tolerance; (U)Heat

23. TECHNICAL OBJECTIVE. 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The identification and investigation of measures designed to prevent or reduce the disabilities, injuries or performance decrements associated with military operations in the heat. Additionally, the study of factors which predispose to heat injury.

24. (U) A variety of preventive measures, e.g. prehydration, dietary supplementation and pharmacological agents, will be evaluated for their effectiveness in protecting from heat injury. Models will be used to elucidate the role of obesity, dehydration, alcohol, drugs, etc, in predisposing to heat illness.

25. (U) 79 10 - 80 09 Because prolonged use of the commonly prescribed phenothiazine agents has been hypothesized to predispose individuals to heat illness, chlorpromazine (CPZ) was administered to adult rates. This treatment reduced their endurance capacity when they were exercised to hyperthermic exhaustion in a hot environment. Thermoregulation was adversely affected as manifested in increased increments in rectal temperature while on the treadmill. The CPZ-treated animals demonstrated exacerbated effects on the pathochemical indices of heat/exercise injury. We have also demonstrated that hyperthermia, elicited by the central administration of prostaglandin E_1 (PGE_1) to normothermic animals, reduced the endurance capacity of rats exercising in the heat by 34%. However, while several indices of heat/exercise injury, such as plasma lactate, potassium, and urea nitrogen, were significantly elevated following exercise to hyperthermic exhaustion, PGE_1 hyperthermia had no effect on these factors. In separate rat studies it was documented that indocyanine green (IGG) can be used to assess both liver function and plasma volume. The rapid clearance of ICG, unlike Evans Blue, permits remeasurement of plasma volume within an hour.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical I .ctors in Military Performance
Work Unit:	005 Models of Heat Disabilities: Preventive Measures
Study Title:	Artificial Heat Acclimatization and the Prevention of Heat Illness.
Investigators:	William R. Sandel, CPT, MSC, Roger W. Hubbard, Ph.D., and Milton Mager, Ph.D.

Background:

In a human study of body fluid adjustments to exercise in a hot, humid environment, although there were individual differences, classical heat acclimatization responses were reported for the group as a whole (1). It was reported that plasma volume expansion was responsible for the acclimatization process. In rats, prehydration and fluid replacement were reported to be essential factors in preventing or forestalling heatstroke mortality (2). It also has been demonstrated that percent mortality (3) and the rate of water loss (4) were greater with exercise and hyperthermia than hyperthermia alone. Therefore, it is reasonable to assume that exercise-induced exhaustion and susceptibility to heat illness may share a common denominator (i.e. plasma volume reduction). By the same reasoning, plasma volume expansion through endurance training and/or heat acclimatization could improve exercise performance and reduce susceptibility to heat illness. This hypothesis and its implications are especially applicable in the prevention of heat casualties among ground troops operating in hot environments, such as the desert or jungle. As such, the purposes of this study are to determine in the rat (a) the relationship between plasma volume levels and exercise endurance and resistance to heat illness before and after exposure, (b) if plasma volume expands in the heat-exposed (acclimatized) and/or exercised (trained) rat, (c) if expansion persists, (d) if expansion improves performance, and (e) if expansion confers protection against heat illness.

Progress:

Our initial research goal was the establishment of an accurate, reproducible, quick-sample method of plasma volume determination. Although the Evans Blue dye-dilution technique is used customarily, the adaptation of indocyanine green (ICG) to determine rat plasma volume offered the potential advantage of determining rat liver function as well. Both plasma volume and liver function are known to be significantly altered during heat stress. However, we were concerned that ICG might be removed too rapidly from the circulation to permit adequate mixing. This raised serious questions as to the validity of using ICG for measuring plasma volumes and, therefore, we decided to compare plasma volume values determined by ICG and the traditional dye-dilution technique. ICG use, if successful, offered the additional advantage of remeasurement of plasma volume due to its rapid clearance during the experiment. These experiments were conducted using control male Sprague-Dawley rats 270-650 gm body weight.

All blood samples were drawn via a jugular cannula at timed intervals after a known quantity of dye was injected. The dye was dissolved in 5% BSA with physiological concentrations of sodium and potassium.

The data that follow compare the results of the ICG dye-dilution experiments to those of Evans Blue. The Student t-test was used to determine statistical significance, and differences between means resulting in $P < 0.05$ were considered significant (5). To date all statistical analyses are not complete. As reported in Table 1, body weights for both groups of animals were not significantly different ($p > 0.05$). Differences in y-intercept (predicted plasma concentration of dye at time = 0 minutes) reflect differences in stock dye concentration administered (2,015 $\pm$ 253 µg/ml for ICG, 3,298 $\pm$ 116 µg/ml for Evans Blue). Differences in slope (Table 1) are an indication of the rate of removal of the dye from the circulation. For example, the slope of the ICG exponential curve is -0.09971 which indicates that approximately 0.09971 x 2.303* x 100 = 22.96% of the remaining dye is removed from the circulation/minute. The Evans Blue slope (-0.00122) indicates that 0.00122 x 2.303* x 100 = 0.28% of the remaining dye is removed/minute. These differences in rates of percent removal are clearly reflected in $t_{1/2}$ (Half-Life in minutes) values reported in Table 1. The $t_{1/2}$ of the ICG and Evans Blue groups were 3.11 + 0.52 (n = 130) and 256.20 + 139.15 (n = 83) minutes, respectively, and the corresponding K constants (min.^{-1}) were $2.3 \times 10^{-1} \pm 3.9 \times 10^{-2}$ (n = 130) and $2.4 \times 10^{-3} \pm 1.7 \times 10^{-3}$ (n = 83). Differences in plasma volume (PV) are shown in Table 1 and indicate, along with plasma volumes/100 gm body weight, that although these values are less in both cases for the ICG groups, the differences are not significant ($p > 0.05$).

The total protein mass (TPM, mg) was 1,428 $\pm$ 264 (n = 134) and 1,599 $\pm$ 282 (n = 100) for the ICG and Evans Blue groups (Table 1), respectively, ($p > 0.05$).

Normalizing for differences in body weight gives a TPM/100 gm body weight of 294 $\pm$ 56 (n = 134) and 330 $\pm$ 58 (n = 100) for the ICG and Evans Blue groups (Table 1), respectively ($p > 0.05$).

Plasma protein concentrations (gm of protein/100 ml of plasma) of both test groups are reported in Table 2. The "Pre" values are those taken for "blanks" or baseline levels, and are not different for the two groups ($p > 0.05$).

Corrected hematocrits of both groups are reported in Table 3. The "Pre" values were not different ($p > 0.05$). Core temperatures (Tc) are reported in Table 4. The "Pre" values were not different ($p > 0.05$). *Conversion factor of $\log_{10}$ values to natural logs (Ln).

The data indicate that both groups were similar ($p > 0.05$) for body weight, plasma volume, "Pre" plasma protein concentrations, corrected hematocrits, and core temperatures. With the data at hand it has been tentatively concluded that ICG can be used to reliably determine plasma volume in rats with the added advantage that it can be used to determine liver function and remeasurement of plasma volume within an hour.

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TABLE I

Preliminary Data Comparing ICG and Evans Blue Plasma Volume Determinations in Rats

	ICG	Evans Blue
Body Weight (gm)	493 ± 71[1] (134)[2]	491 ± 80[1] (100)[2]
Y-Intercept	108.8 ± 15.1 (130)	159.3 ± 27.2 (100)
Slope	-0.09971 ± 0.017 (130)	-0.00122 ± 9.1 x 10^{-4}(100)
PV (ml)	19.09 ± 2.86 (134)	21.30 ± 3.51 (100)
PV/100 gm BW (ml/100 gm)	3.93 ± 0.67 (134)	4.93 ± 0.69 (100)
t 1/2 (min)	3.11 ± 0.52 (130)	256.20 ± 139.15 (83)
k (min^{-1})	2.3 x 10^{-1} ± 3.9x 10^{-2} (130)	3.4 x 10^{-3} ± 1.7 x10^{-3} (83)
TPM (mg)	1428 ± 264 (134)	1599 ± 282 (100)
TPM/100 gm BW (mg/100 gm)	294 ± 56 (134)	331 ± 58 (100)
BW Range (gm)	270 - 611 (134)	310 - 650 (100)

[1]All values are X ± SD$\bar{x}$.
[2]Numbers in parenthesis = n.

NOTES:

1.0 ml of ICG was injected at 2,015 ± 253 µg/ml (n = 49); 1.0 ml of Evans Blue was injected at 3,298 ± 116 µg/ml (n=45).

ICG molar extinction coefficient (E) = 1.05 x 10^5 cm^2/mole; Evans Blue molar extinction coefficient (E) = 0.088 x 10^5 cm^2/mole.

ICG max = 805 mµ; Evans Blue max = 618 mµ .

PV = Plasma volume; BW = Body weight; TPM = Total Protein Mass.

TABLE 2

Plasma Protein Concentrations (gm/100 ml Plasma)
of ICG and Evans Blue Rats

ICG			Evans Blue		
Pre	7.46 ± 0.48[1]	(134)[2]	Pre	7.50 ± 0.40[1]	(100)[2]
1.0 Min.	7.48 ± 0.50	(82)	10 Min.	7.24 ± 0.39	(100)
2.0 Min	7.06 ± 0.45	(56)	20 Min.	7.13 ± 0.37	(100)
3.5 Min.	7.27 ± 0.44	(55)	30 Min.	7.06 ± 0.41	(100)
5.0 Min.	7.12 ± 0.48	(81)	40 Min.	7.01 ± 0.38	(100)
6.0 Min.	7.22 ± 0.45	(53)	50 Min.	6.94 ± 0.41	(100)
7.0 Min.	6.99 ± 0.50	(55)	60 Min.	6.86 ± 0.40	(100)
8.5 Min.	7.27 ± 0.48	(51)			
10.0 Min.	7.16 ± 0.47	(80)			

[1]Values are $X \pm SD\bar{x}$

[2]Numbers in parenthesis = n.

TABLE 3

Hematocrits of ICG and Evans Blue Rats*

ICG			Evans Blue		
Pre	40.3 ± 3.7[1]	(133)[2]	Pre	41.1 ± 3.8[1]	(100)[2]
1.0 Min.	36.8 ± 3.4	(81)	10 Min.	39.2 ± 3.5	(100)
2.0 Min.	39.7 ± 3.7	(56)	20 Min.	38.8 ± 3.2	(100)
3.5 Min	36.5 ± 3.5	(54)	30 Min.	37.9 ± 3.5	(100)
5.0 Min.	38.6 ± 3.3	(80)	40 Min.	37.9 ± 3.7	(100)
6.0 Min.	36.6 ± 3.5	(53)	50 Min.	37.6 ± 3.6	(100)
7.0 Min.	38.7 ± 3.3	(54)	60 Min.	37.5 ± 3.5	(100)
8.5 Min.	36.1 ± 3.7	(51)			
10.0 Min.	37.4 ± 3.6	(80)			

*Corrected for plasma trapping.

[1]Values are $X \pm SDx$

[2]Numbers in parenthesis = n.

TABLE 4

Core Temeratures (Tc) in C of ICG and Evans Blue Rats

ICG			Evans Blue		
Pre	38.6 ± 0.6[1]	(133)[2]	Pre	38.6 ± 0.6[1]	(100)[2]
0 Min.	38.7 ± 0.6	(133)	0 Min.	38.6 ± 0.5	(100)
1.0 Min.	38.8 ± 0.7	(81)	10 Min.	38.8 ± 0.5	(100)
2.0 Min.	38.7 ± 0.6	(56)	20 Min.	38.9 ± 0.6	(100)
3.5 Min.	38.8 ± 0.8	(54)	30 Min.	39.0 ± 0.6	(100)
5.0 Min.	38.8 ± 0.5	(80)	40 Min.	39.0 ± 0.7	(100)
6.0 Min.	38.8 ± 0.8	(53)	50 Min.	39.1 ± 0.7	(100)
7.0 Min.	38.7 ± 0.6	(54)	60 Min.	39.0 ± 0.7	(100)
8.5 Min.	38.8 ± 0.8	(51)			
10.0 Min.	38.8 ± 0.7	(81)			

[1]Values are $X \pm SD\bar{x}$.

[2]Numbers in parenthesis = n.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	005 Models of Heat Disabilities: Preventive Measures
Study Title:	Heat Injury: Studies on Mechanisms, Prevention and Predisposition
Investigators:	Ralph P. Francesconi, Ph.D. and Milton Mager, Ph.D.

Background:

One of our primary areas of interest has been the identification, investigation, and quantitation of factors which can predispose individuals to heat injury. Thus, in an earlier publication (1) we have reported preliminary results from a study quantitating the debilitating effects of chronic alcohol consumption on the ability to perform physical work in the heat. In this present document, we will complete the report of the results of that study as well as two additional investigations: the effects of chronic chlorpromazine administration on the ability to work in the heat, and the effects of elevated body temperature on the ability to work in the heat.

All three of these apparently dissimilar factors have been hypothesized to impact adversely on physical performance in a hot environment. It was anticipated that alcohol, vis-a-vis its dehydrational effects and its inhibitory effects on albumin biosynthesis (2), might attenuate normal physiological mechanisms involving protein and water influx into the circulatory system which must occur for individuals to work successfully in the heat (3). Chlorpromazine (CPZ) a commonly used anti-depressant, has been hypothesized to interfere with thermoregulation by interfering with normal heat-loss pathways (4,5,6). Additionally, a variety of recent publications (7-10) noted that infectious diseases with accompanying pyrexia will predispose the afflicted individuals to an increased risk of serious heat injury if the ambient and/or work conditions are oppressive.

However, it is noteworthy that despite the theorized decrements in performance under the influence of these disparate factors, we were unaware of any reports quantitatively describing the physiological cost or the severity of the heat injury incurred when exercise in the heat follows the development of conditions which may exacerbate such injury. Accordingly, we undertook a systematic investigation to identify and quantitate the pathophysiological, thermoregulatory, and clinical chemical effects of chronic ethanol consumption, CPZ administration, and preinduced hyperthermia on the ability to exercise in the heat.

Progress:

Adult, male rats, weighing between 250 g - 350 g, were used in all experiments. For the ethanol (ETOH) experiments, alcohol/water mixtures (4,8,12 or 16% of 100% ETOH in water) were supplied to the rats as the sole source of drinking water for two weeks prior to the heat/exercise experiment. For the CPZ experiments a separate group of rats were injected daily for 14 consecutive days by intraperitoneal injection with a solution containing 2 mg chlorpromazine (Thorazine®, Smith, Kline, and French Labs, Philadelphia). In order to induce a persistent, low-grade fever in otherwise normal rats, it was first necessary to implant surgically a stainless steel cannula intracerebroventricularly for direct injection into the central nervous system, proximal to the sites of temperature regulation. On the day of the experiment consistent elevations in rectal temperature (Tre) were elicited by injecting centrally 40µg of prostaglandin E_1 (PGE_1), a substance often used to induce hyperthermia in mammalian organisms. On the day prior to the experiment all animals were fitted with indwelling jugular catheters for the removal of a small volume of blood (1 ml) prior to and subsequent to exercise (level treadmill, 9.14 m/minute) in a hot (35°C, 25% RH) environment to hyperthermic exhaustion (Tre = 42.5°C - 43.0°C). Hematocrits were obtained for all blood samples and following centrifugation, plasma samples were deep-frozen for subsequent analysis of the clinical chemical indices of heat/exercise injury.

During the current FY data for all three substudies have been collected and analyzed. For each study figures and tables will be presented to illustrate thermoregulatory, physiological, and clinical chemical data as mean values for both experimental and control groups.

The first five figures and one table collate data gathered in the ETOH consumption study. The treadmill endurance capacity of rats consuming 4% ETOH (n=9, 32.0 ± 1.0 minutes) was essentially identical to that of a group of controls (rats consuming water, n=13, 32.9 ± 1.65 minutes). Likewise, thermoregulatory measures as well as clinical chemical indices of heat/exercise injury were similar between control rats and those consuming 4% ETOH. As a result of these similarities, analyses of variance were performed on data obtained from the four groups of rats consuming increasing concentrations of ETOH. Figs. 1 and 2 demonstrate the effects of the four levels of ETOH on the Tre and Tsk responses, respectively, to exercise in the heat to hyperthermic exhaustion.

In both figures the arrows denote the mean endurance capacity (treadmill time) for each group of rats. Note that prolonged ETOH consumption had no effects on the basal Tre and Tsk measured for these animals (time 0). Table 1 summarizes and quantitates some of the data depicted in Figures 1 and 2.

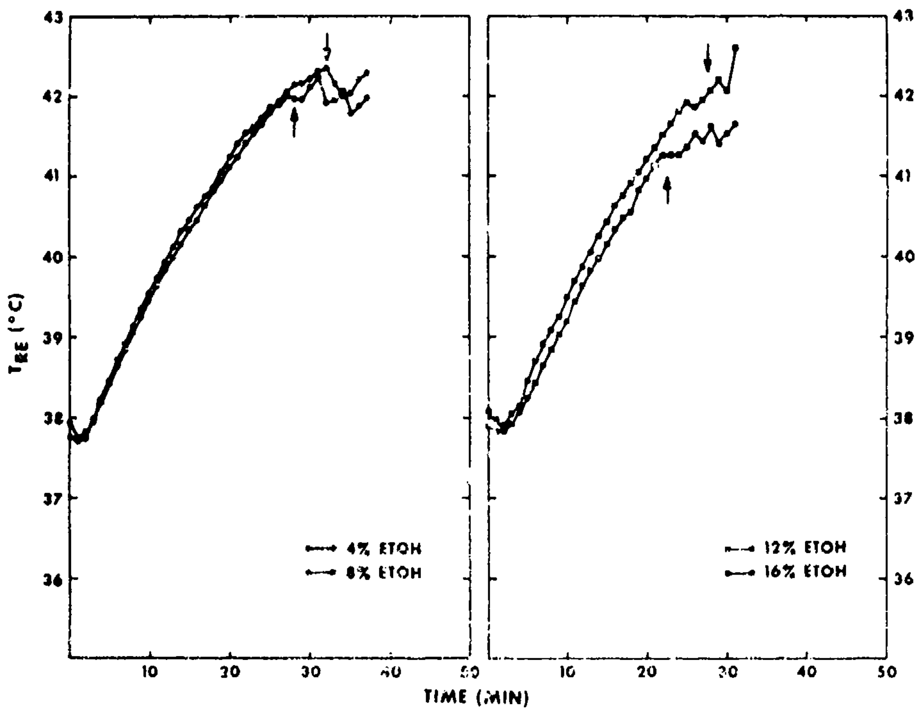

Figure 1. Effects of chronic ingestion of ethanol on the rectal temperature response to exercise in the heat. The arrows denote the average endurance capacity for each group of animals.

Endurance capacity for animals consuming 4% ETOH or 8% ETOH both differed significantly ($p < .05$) from that of animals consuming 16% ETOH. The reduced treadmill time of the rats drinking 16% ETOH is reflected in a reduced maximal Tre ($p < .05$) when compared with either the 4%, 8%, or 12% group while increments on the treadmill (ΔTre/min) are not significantly affected by increased alcohol levels. Tsk max was significantly lower ($p < .05$) in the 16% group when compared with the 4% group while increments in Tsk were unaffected. Figure 3 illustrates the effects of consumption of increasing concentrations of ETOH on plasma lactate levels after exercise in the heat.

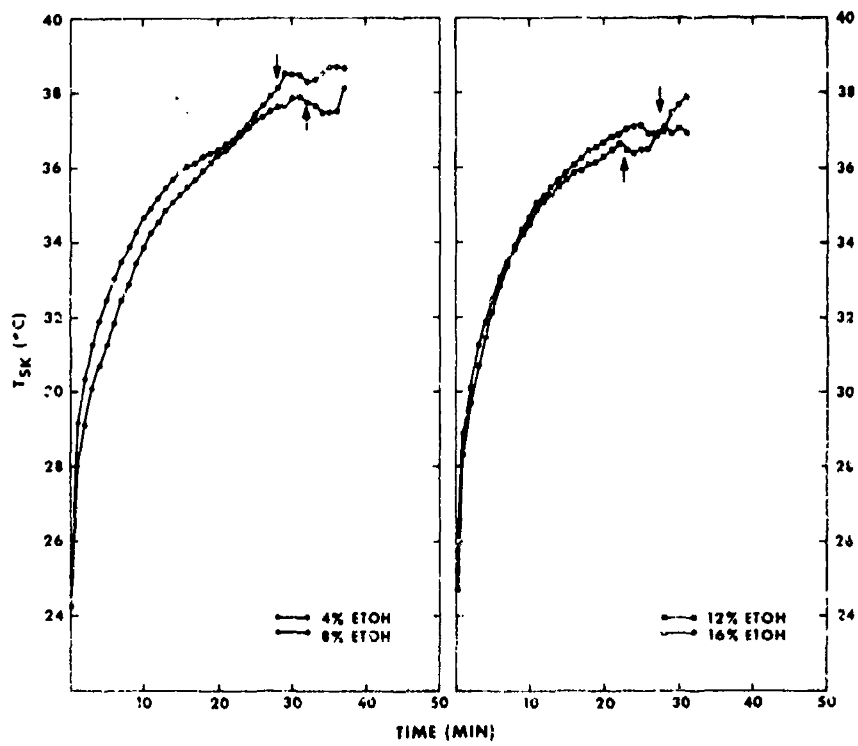

Figure 2. Effects of chronic ingestion of ethanol on the skin temperature response to exercise in the heat. The arrows denote the average endurance capacity for each group of rats.

TABLE 1

Quantitation of the data depicted in Figures 1 and 2

		TIME ON TREADMILL (MINUTES)	RECTAL TEMPERATURE MAXIMUM (°C)	ΔT_{RE}/MIN ON TREADMILL (°C)	SKIN TEMPERATURE MAXIMUM (°C)	ΔT_{SK}/MIN ON TREADMILL (°C)	VOLUME CONSUMED
4% ETOH	$\bar{X}$	32.0	42.63	.153	37.81	.423	351.3
	$SE_{\bar{X}}$	1.0	.09	.009	.24	.018	17.9
8% ETOH	$\bar{X}$	28.09	42.37	.160	37.26	.438	259.1
	$SE_{\bar{X}}$	1.40	.13	.009	.34	.016	18.6
12% ETOH	$\bar{X}$	27.62	42.30	.153	37.25	.454	323.6
	$SE_{\bar{X}}$	.80	.13	.004	.34	.02	27.3
16% ETOH	$\bar{X}$	22.72	41.22	.145	36.22	.511	252.3
	$SE_{\bar{X}}$	1.94	.36	.010	.43	.039	19.1

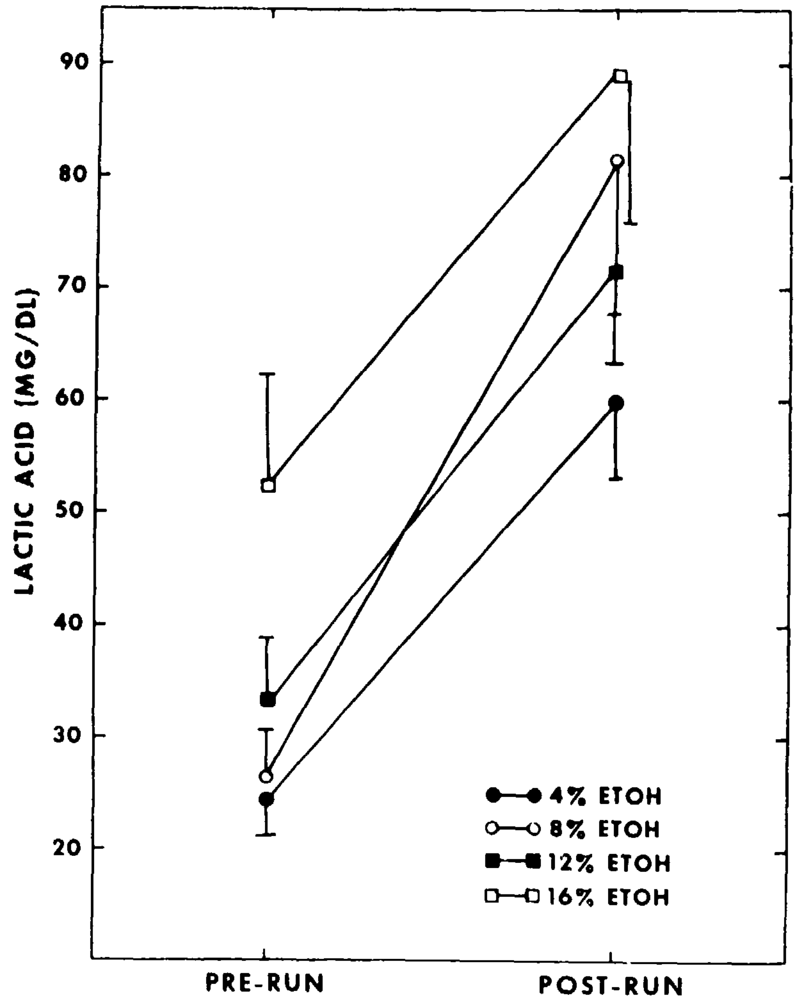

Figure 3. Effects of consumption of increasing levels of ETOH on the plasma lactate response to exercise in the heat.

While resting (pre-run) levels of plasma lactate demonstrated a trend toward increasing concentrations in association with increasing ETOH levels, rather large variability precluded significance among these samples. As anticipated, for each group of rats there was a highly significant ($p < .001$) increase in lactate levels when the concentration of lactate in each pre-run sample was compared with its corresponding post-run counterpart. Analogous responses are demonstrated for plasma potassium (K^+) levels in Figure 4 with highly significant ($p < .001$) increments between pre- and post-run samples noted for all 4 groups. Data on creatine phosphokinase (CPK) levels (Figure 5) generally indicated that rats consuming the higher concentrations of ETOH demonstrated significantly

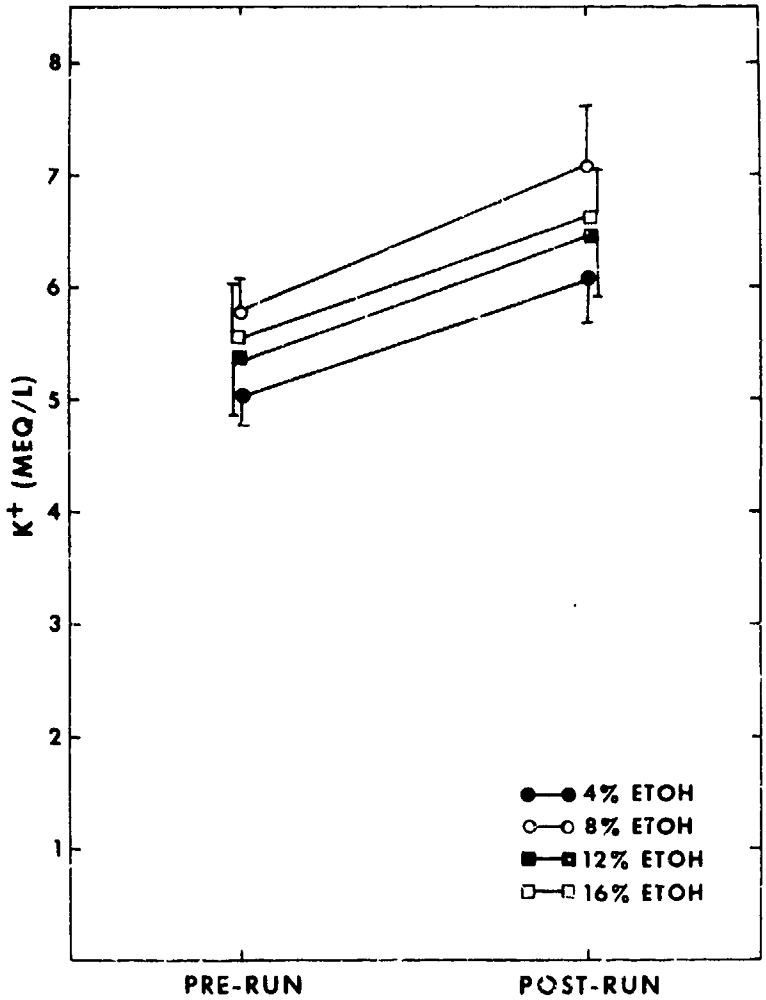

Figure 4. Effects of consumption of increasing levels of ETOH on the plasma potassium response to exercise in the heat.

increased levels of CPK following the run to hyperthermic exhaustion (e.g. post-run: 4% vs 12%, 4% vs 16%, 8% vs 16%, all $p < .05$). Likewise although the rats which consumed 16% ETOH had the lowest endurance capacities, CPK was significantly ($p < .05$) increased in this group between the pre- and post-run samples. It is important to add that increasing concentrations of ETOH had no effects on resting hematocrit levels (e.g. pre-run, Hct, 4% vs 16%, 41.9 $\pm$ 1.3 vs 43.7 $\pm$ 1.0, $p > 0.1$). Likewise, total protein measures were unaffected by increasing concentrations of ETOH (e.g. pre-run, total protein in g/dl, 4% vs 16%, 5.3 $\pm$ .22 vs 6.01 $\pm$ .16, $p = 0.09$).

Although we had previously demonstrated that the hypothermia elicited by acute administration of CPZ can prolong endurance capacity in the heat (11), we were unaware of any reports quantitating the degree of disability accrued by chronic usage of CPZ prior to exercise under hot environmental conditions.

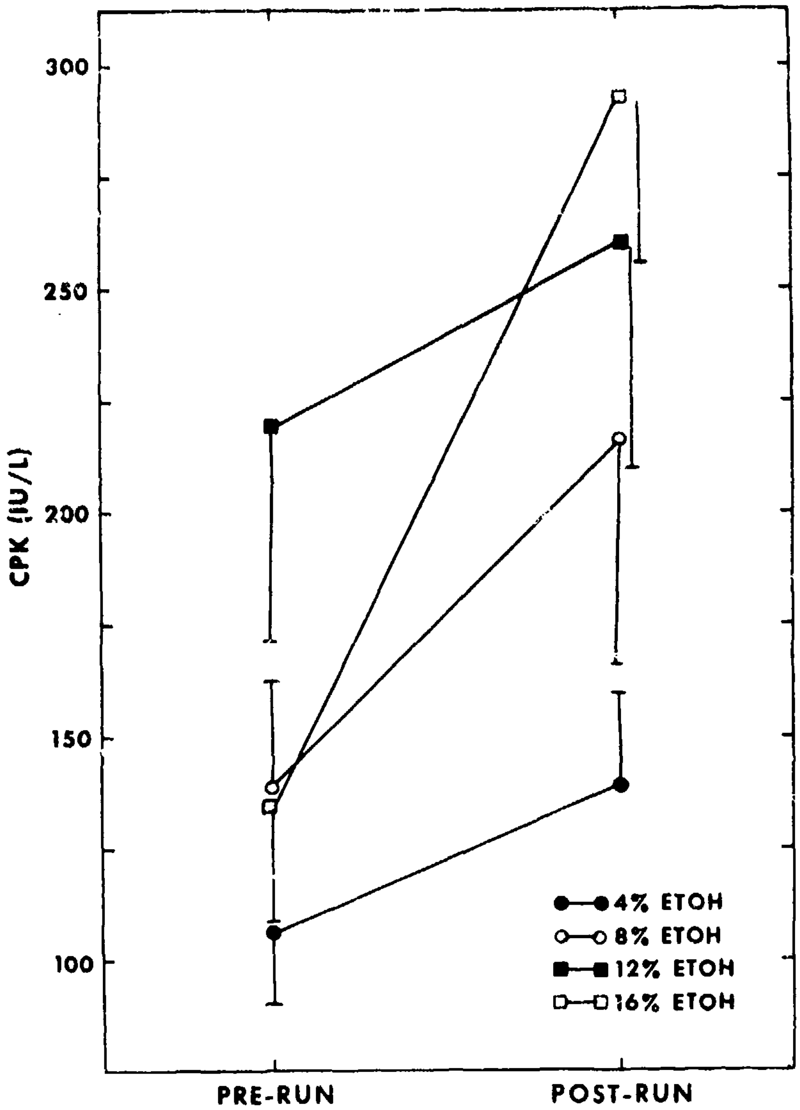

Figure 5. Effects of consumption of increasing levels of ETOH on the CPK activity in plasma samples immediately prior to and subsequent to exercise in the heat.

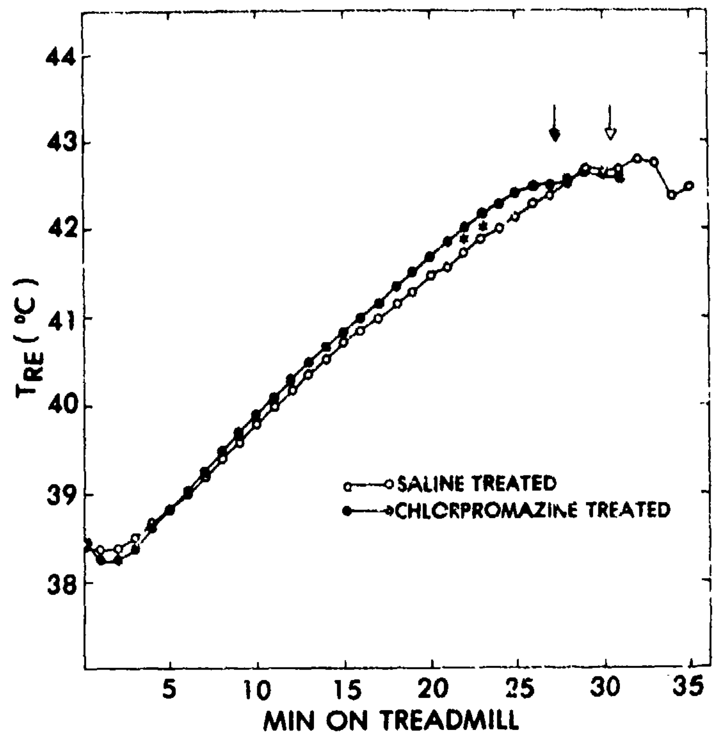

Figure 6. Effects of chronic chlorpromazine administration on the Tre response to exercise in the heat. The arrows indicate the mean endurance capacity for each group of rats.

Figure 6 depicts the rectal temperature response to exercise in the heat in the CPZ-treated rats and a group of saline-treated controls. It is interesting to note that at each 1 minute interval between 7 and 27 minutes, saline-treated control rats have a consistently lower Tre than the CPZ-treated group. This trend achieves significance at 22 and 23 minutes ($p < .05$, one-tailed, paired t test). Figure 7 illustrates the response of skin temperature to moderate exercise in a hot environment for the experimental and control groups of rats.

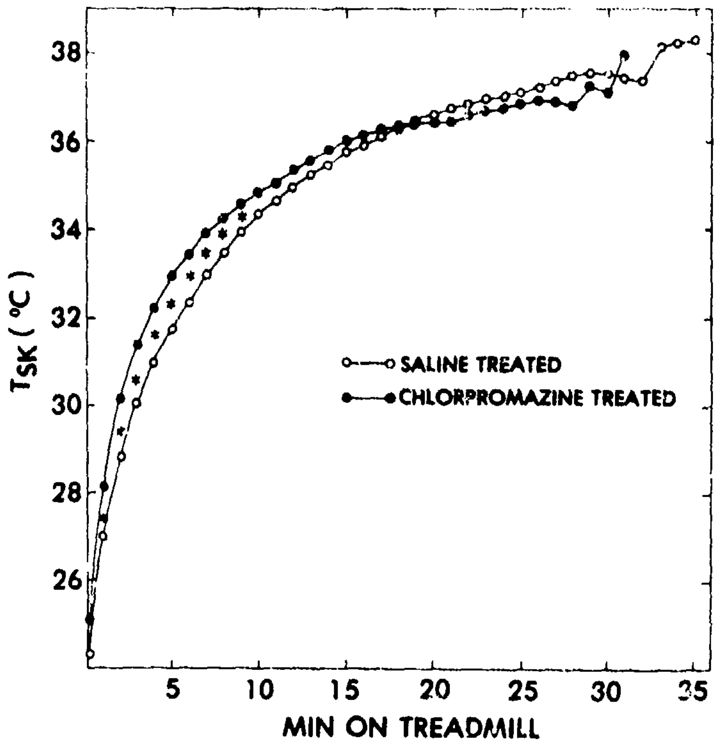

Figure 7. Effects of chronic CPZ administration on the tail-skin temperature response to exercise in the heat.

The pattern of response demonstrates that through 17 minutes on the treadmill the CPZ-treated animals actually have a higher Tsk than the saline-treated controls. In fact, between 1 and 9 minutes (but not at time 0) Tsk among CPZ-treated rats are significantly higher ($p < .05$ - $p < .001$, non-paired t test). However, it is important to add that after 20 minutes, this pattern is reversed, and the treadmill runs concluded with control animals having the higher Tsk readings. The results graphically illustrated in Figs. 6 and 7 are summarized and quantitated in Table 2. These data demonstrate that the approximate 10% reduction in treadmill time between the CPZ- and saline-treated animals represents a highly significant decrement. Further, the consistently increased Tre among CPZ-treated animals demonstrated in Figure 6 translate also into a significant increment in Tre when the data are compared per unit time while the animals were on the treadmill. Alternatively, increments in Tsk are not significantly different between the two groups. Table 3 summarizes and compares the clinical chemical data observed for both groups of animals.

TABLE 2

Quantitation and statistical analysis of the data presented in Figures 6 and 7

	TIME ON TREADMILL (MIN)	RECTAL TEMPERATURE MAXIMUM(°C)	ΔT_{RE} / MIN ON TREADMILL (°C)	SKIN TEMPERATURE MAXIMUM(°C)	ΔT_{SK} / MIN ON TREADMILL (°C)
CONTROL					
n=16 $\bar{X}$	30. 50	42.85	.146	37.43	.430
SD_X	2.28	.308	.017	1.02	.031
CPZ					
n=17 $\bar{X}$	27.41	42.84	.161	36.98	.434
SD_X	2.15	.29	.016	.87	.078
t	4.00	.046	2. 489	1.37	.164
P	<.001	NS	<.02	NS	NS

Initially, it should be pointed out that the significance levels noted in parentheses resulted from paired t tests performed on the data collected from the same animals before and after the run to hyperthermic exhaustion. The t values and p values noted in the lower portion of the table refer to non-paired t tests comparing data of the control and CPZ-treated animals. The significant ($p < .001$) increments noted in the lactate and potassium levels pre-and post-run are consistently observed in animals exercised to hyperthermic exhaustion. When comparing the levels of these pathochemical indices of heat/exercise injury in the CPZ treated and control groups, it is of interest that a pattern of higher levels emerged for each metric in the CPZ-treated animals. For lactate concentrations in the post-run blood samples, a significant ($p < .05$) increase occurred. As noted in Table 4 glucose levels were unaffected by either the CPZ treatment or the exhaustive run in the hot environment while sodium levels were increased in both groups by the heat/exercise regimen.

TABLE 3

Plasma lactate, potassium, and CPK levels in blood samples of experimental and control rats, immediately prior to and subsequent to exercise in the heat to hyperthermic exhaustion.

	LACTATE (MG/DL)			POTASSIUM (MEQ/L)			CREATINE PHOSPHOKINASE (IU/L)		
	PRE-RUN		POST-RUN	PRE-RUN		POST-RUN	PRE-RUN		POST-RUN
CONTROL									
$\bar{X}$	25.08	(P<.001)	48.79	5.39	(P<.001)	6.31	73.98	(P=NS)	81.23
SD_X	10.44		20.16	.59		.74	26.67		39.49
CPZ									
$\bar{X}$	32.71	(P<.001)	70.54	5.53	(P<.001)	7.03	94.34	(P=NS)	108.68
SD_X	17.8		34.48	.66		1.33	54.04		69.88
t	1.49		2.19	.59		1.88	1.33		1.34
P	NS		<.05	NS		NS	NS		NS

TABLE 4

Plasma sodium and glucose levels in blood samples of control and CPZ-treated rats immediately prior to and subsequent to exercise in the heat to hyperthermic exhaustion.

	SODIUM (MEQ/L)			GLUCOSE (MG/DL)		
	PRE-RUN		POST-RUN	PRE-RUN		POST-RUN
CONTROL						
$\bar{X}$	143.3	(P<.02)	152.4	151.8	(P= NS)	145.35
SD_X	9.18		10.67	5.5		48.9
CPZ $\bar{X}$	143.1	(P<.005)	152.4	149.2	(P= NS)	136.0
SD_X	10.14		8.28	19.1		44.3
t	.075		.004	.423		.597
P	NS		NS	NS		NS

In order to elicit consistent hyperthermia in rats, it was necessary to introduce the pyrogen directly into the central nervous system. Previously, we found that hyperpyrexia could not be elicited by parenteral administration of lipopolysaccharide of S. abortus equi, S. typhimurium, E. coli, or Pseudomonas, even in high dosages. Therefore, we implanted by stereotaxic means stainless steel cannulae into the lateral cerebral ventricle. By injecting microgram quantities of prostaglandin E_1 (12-14), we successfully produced consistent hyperthermia of $2^{o}C$ within 20-30 minutes. These hyperthermic rats then were exercised in a hot environment and thus served as models to determine the effects of preinduced hyperthermia on the ability to exercise in the heat.

Figure 8 illustrates the core temperature response to exercise in the heat of a PGE_1-treated, initially hyperthermic and a saline-treated, initially normothermic group of rats. The data indicate that the PGE_1-treated animals

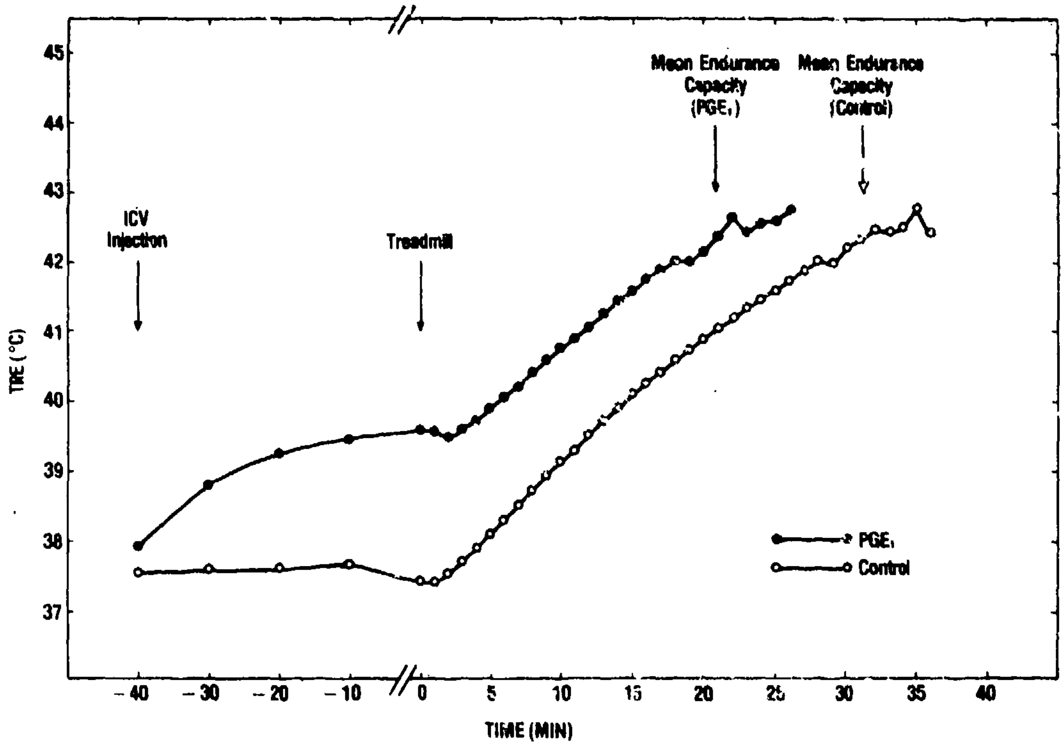

Figure 8. Effects of PGE_1 hyperthermia on the rectal temperature response of rats to exercise in the heat. At time -40, 40μg PGE_1/20μl NaCl or 20μl NaCl (physiological, non-pyrogenic) was injected into each of the experimental and control groups, respectively.

had significantly increased Tre ($p < .001$) between 0 and 17 minutes, the time at which one of the initially hyperthermic animals reached hyperthermic exhaustion. Figure 9 depicts the skin temperature response to moderate exercise in a hot environment for the two groups of animals under investigation. The results demonstrated in Figures 8 and 9 are summarized and quantitated in Tables 5 and 6. The data in Table 5 clearly demonstrate that the PGE_1 hyperthermia significantly ($p < .001$) reduces (21.42 vs 32.33 minutes) the endurance capacity of the originally hyperthermic rats although Tre max and Tsk max are unaffected by the pretreatment. In Table 6, the significantly ($p < .005$) greater increments in Tre per minute for the first 20 minutes on the treadmill among the control animals is appropriate since the heat gain per unit time for the cooler control animals would be greater during this interval. We had previously demonstrated this effect in several earlier publications (11,15). Over the entire treadmill time, however, this effect is diluted by the greater

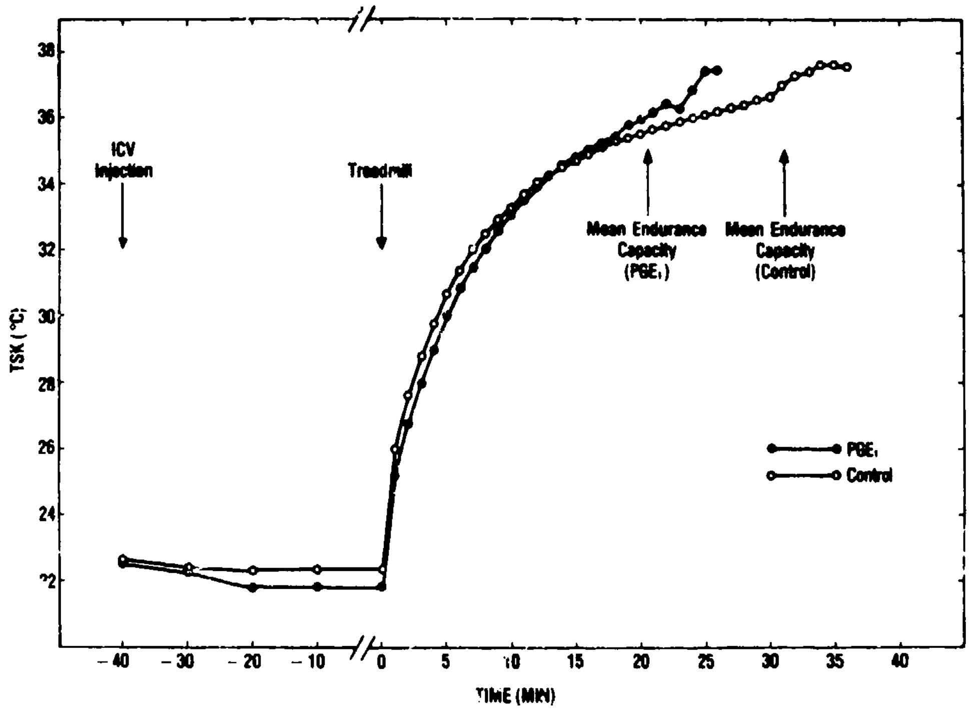

Figure 9. Effects of PGE_1-induced hyperthermia on the skin temperature response of rats to exercise in the heat.

TABLE 5

Summary of the data depicted in Figures 8 and 9

	Time on Treadmill (MIN)	Rectal Temperature Maximum (°C)	Skin Temperature Maximum (°C)
Control			
n	12	12	12
$\bar{X}$	32.33	42.45	36.71
$SD_{\bar{x}}$	2.57	.41	1.22
PGE_1			
n	12	12	12
$\bar{X}$	21.42	42.53	35.83
$SD_{\bar{x}}$	3.45	.68	1.31
t	8.79	.363	1.70
p	<.001	NS	NS

interval on the treadmill in the case of the control animals. Analogously, the significant increase in Tsk/minute ($p < .001$) among PGE_1-treated rats over the entire treadmill time appears to be a function of the reduced endurance capacity among these animals since between 0-10 and 0-20 minutes, significance is not achieved between these two groups.

Figure 10 demonstrates that the initial hyperthermia induced by central administration of PGE_1 had no significant effects on the plasma levels of urea nitrogen (UN) or lactate. In both groups of animals significant ($p < .001$) increments were recorded for both indices of heat/exercise injury when pre-run levels were compared with post-run levels. This indicates that the hyperthermia, per se, induced passively by PGE_1 administration, had no effect upon these pathochemical correlates. Figure 11 depicts data demonstrating that exercise in the heat to hyperthermic exhaustion results in significant increments in plasma

Table 6

Quantitation and analysis of the data presented in Figs. 8 and 9.

	ΔTRE/Min First 10 min. interval on treadmill (°C/Min)	ΔTSK/Min First 10 min. interval on treadmill (°C/Min)	ΔTRE/Min First 20 min. interval on treadmill (°C/Min)	ΔTSK/Min First 20 min. interval on treadmill (°C/Min)	ΔTRE/Min Entire interval on treadmill (°C/Min)	ΔTSK/Min Entire interval on treadmill (°C/Min)
Control						
n	12	12	12	12	12	12
$\bar{X}$	.142	.987	.161	.650	.153	.451
SD_x	.019	.293	.016	.062	.01	.041
PGE_1						
n	12	12	8*	8*	12	12
$\bar{X}$	.120	1.044	.133	.723	.140	.679
SD_x	.033	.311	.02	.08	.021	.69
t	1.951	.378	3.49	2.02	1.93	7.855
p	NS	NS	p<.005	NS	NS	p<.001

*Four rats failed to run for 20 min.

levels of potassium in both control ($p < .01$) and PGE_1-treated ($p < .02$) rats. Less consistent data are recorded when the results for sodium responses are noted. For example, relatively low levels of sodium ($\bar{x}$ = 138.75 mEq/L) in NaCl-treated control rats (pre-run) give rise to significant differences when pre- and post-run samples were compared in this group ($p < .01$) and when PGE_1-treated (pre-run) were compared with NaCl-treated (pre-run) ($p < .02$). No significant effects were noted in CPK levels (Figure 12) in either the control or experimental group.

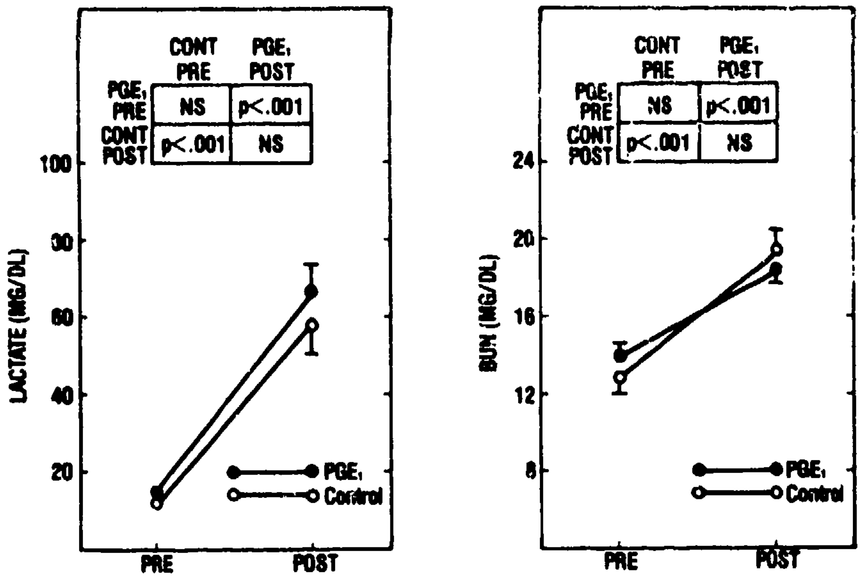

Figure 10. Effects of PGE_1 hyperthermia on plasma levels of lactate and UN in blood samples taken immediately prior to and subsequent to exercise in the heat to hyperthermic exhaustion.

However results noted also in Figure 12 demonstrate that following exercise to hyperthermic exhaustion plasma glucose levels are reduced in both the PGE_1-treated group ($p < .005$) and the NaCl-treated group ($p < .05$). Further, control levels of plasma glucose are reduced significantly ($p < .05$, pre-run) when compared with levels recorded for PGE_1-treated rats.

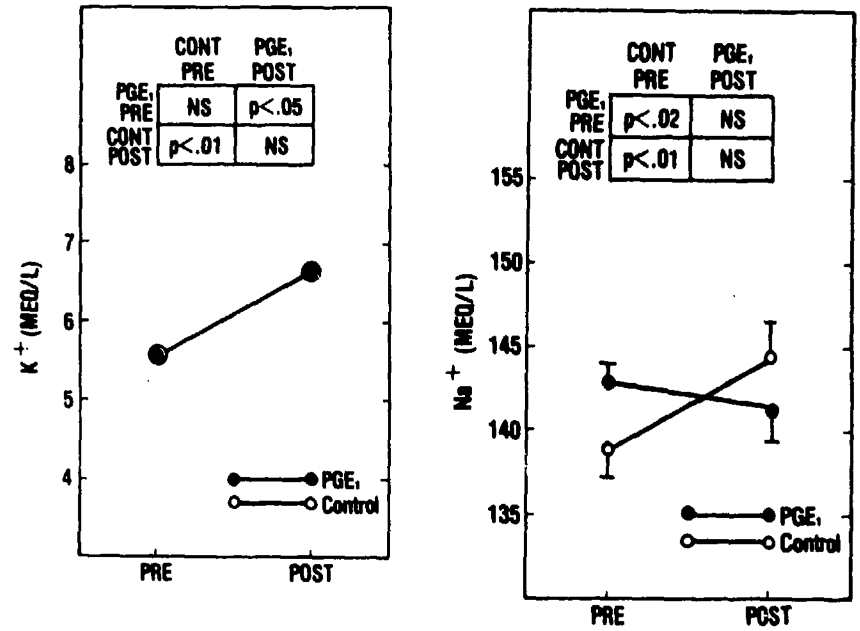

Figure 11. Effects of PGE hyperthermia on plasma levels of potassium and sodium before and after exercise in the heat to hyperthermic exhaustion.

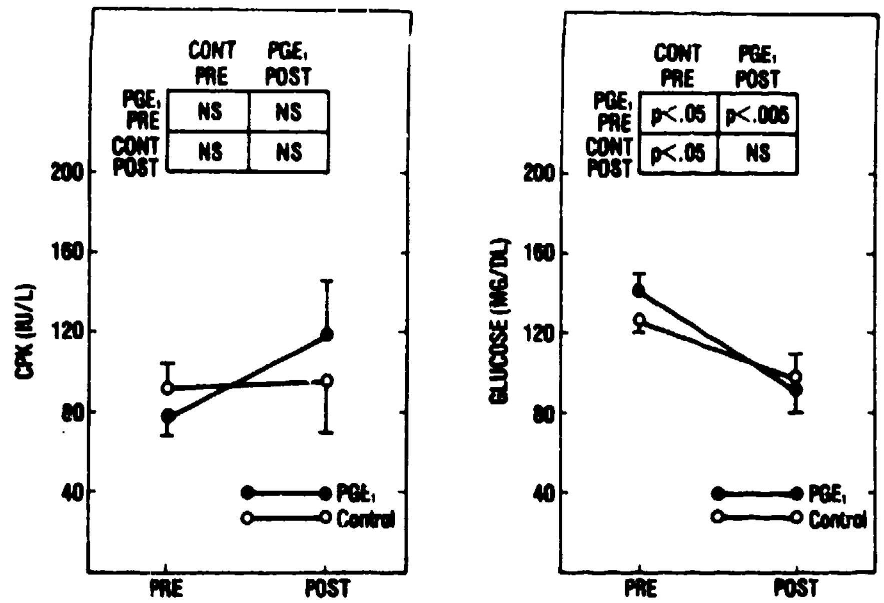

Figure 12. Effects of PGE_1 hyperthermia on plasma levels of CPK and glucose before and after exercise in the heat to hyperthermic exhaustion.

We concluded from these studies that comsumption of increasing levels of alcohol, chronic usage of chlorpromazine, and PGE_1 induced hyperpyrexia may adversely affect the ability to perform physical work in the heat. While consumption of increasing concentrations of ETOH had no effects on hematocrit or plasma proteins, levels of the commonly reported indices of heat/exercise injury (lactate, potassium, CPK) were exacerbated by higher ETOH concentrations as they were in the case of chronic CPZ administration. While PGE_1 hyperthermia reduced performance time, the clinical chemical indices of heat injury were unaffected by initial hyperpyrexia. Additionally, the most marked effects on temperature regulation were elicited by chronic CPZ administration. Thus, we have documented and quantitated the adverse effects of apparently disparate factors on the ability to work in the heat. Of equal importance is the fact that the results of the present experiments have suggested additional investigations to characterize further the mechanism and etiology of heat/exercise injury.

Presentations:

1. Francesconi, R. P. and M. Mager. Effects of hypothermia induced by 5-thio-D-glucose on treadmill performance in the heat. Physiologist. 22:40, 1979. (Presented at the Annual Meeting of the American Physiological Society, New Orleans, LA, October 1979).

2. Mager, M. and R. P. Francesconi. 5-thio-D-glucose: thermoregulatory effects in mice at several environmental temperatures. Physiologist. 22:40, 1979. (Presented at the Annual Meeting of the American Physiological Society, New Orleans, LA, October 1979).

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1. Francesconi, R. P. and M. Mager. Hypothermia induced by chlorpromazine or L-tryptophan: effects on treadmill performance in the heat. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 47:813-817, 1979.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OB 6120	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	X YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61102A	3M161102BS10	CA	009
FORMER	6.11.02.A	3E161102BS08	00	009
c. XXXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)*
(U)Biological Processes that Limit Heavy Physical Work Ability of the Soldier (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:*
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	7.0	116
	CURRENT 81	6.0	93

19. RESPONSIBLE DOD ORGANIZATION
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NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* VOGEL, James A., Ph.D.
TELEPHONE: 955-2800
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: PATTON, John F., Ph.D.
NAME: Knuttgen, Howard K., Ph.D. DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Exercise Capacity; (U)Anaerobic Power; (U)Fatigue; (U)Military Performance; (U)Muscle Fibers, (U)Ergometry

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The combat soldier often depends upon his ability to perform sustained and sometimes severe levels of muscular exertion. The objectives of this research are to a) identify and characterize those biological processes that influence his capacity to perform heavy work, thereby providing a rational basis for improving the soldier's performance; and b) identify the physiological and biochemical processes that occur during physical training both at the whole body and muscle level, thereby providing a rational basis for improving physical training programs.

24. (U) Specific areas of study will include: (1) environmental influences on physiological work capacity and performance, (2) affects of disease or other altered states of the body on exercise performance capacity, (3) development of measures and methods of training for anaerobic fitness, and (4) relationship of muscle histochemistry to muscular strength and endurance.

25. (U) 79 09 - 80 10 Experiments designed to study the influence of muscle fiber type distribution on brief high intensity exercise demonstrated that: a) muscle strength at high contraction velocities was found to correlate with the relative percentage of fast twitch fibers, b) muscle fatigue was not related to fiber type distribution, and c) individuals less susceptible to fatigue demonstrated the most pronounced recovery which appears to be explained by differences in enzyme activity and substrate concentration for anaerobic metabolism.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.02.A. DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08. Environmental Stress, Physical Fitness and Medical Factors in Military Performance.
Work Unit:	009 Biological Processes that Limit Heavy Physical Work Ability in the Soldier
Study Title:	Relationship of muscle fiber types to fatigue, recovery and exercise performance
Investigators:	Per A. Tesch, Ph.D., William L. Daniels, CPT, MSC, Ph.D., Dan S. Sharp, CPT, MC, M.D., James E. Wright, CPT, MSC, Ph.D., and William L. Evans, Ph.D.

Background:

Numerous studies have demonstrated that muscle fiber type composition is one determinant for muscular performance in various modes. Two main fiber types have been distinguished in man: slow twitch (ST or Type I) and fast twitch (FT or Type II) fibers. Differentiation of fiber types is based on differences in contraction speed and this property is related to the activity and the specificity of the enzyme ATPase. In addition to specific contractile properties, the metabolic profile varies significantly when comparing different fiber types. While individual muscle fiber type distribution seems to be established at an early age, the metabolic potential can be altered with modifications in physical activity level. With this as a background the object of the present experiments was to study the influence of muscle fiber type distribution along with less static parameters such as vascularity of the muscle tissue, enzyme activities and oxygen consumption of muscle homogenates on specific performance capacity, cardiovascular response and lactate metabolism.

Progress:

A total of 18 subjects were examined. Their mean (range) age, height, weight and maximal oxygen uptake (cycle ergometer) were 28 (23-44) yr., 177 (165-186) cm, 77 (67-99 kg) and 48 (37-61) ml x kg^{-1} x min^{-1}.

Knee extensor strength (torque) was recorded using an isokinetic device (Cybex II) at low (30^{0} x s^{-1}) and high (180-300^{0} x s^{-1}) contraction velocities. Using the same equipment, muscle fatigue and recovery from fatigue were studied according to the following protocol: Fifty consecutive, voluntary, maximal contractions were repeated at $180^{o} \times s^{-1}$; the relative decrement in force output from the first to the final contractions was calculated and used as an index for fatigue. After a 40 second pause, 5 additional contractions were repeated and force increase was calculated and used as an index for recovery from fatigue. Venous blood samples for further lactate analyses were obtained from an indwelling catheter at rest, in the pause, immediately after and every minute up to 6 minutes after the final contractions.

Within a week's time, two muscle biopsy samples were obtained from m. vastus lateralis at rest. One of the samples was mounted and treated for further histochemical analyses in order to determine muscle fiber type distribution, muscle fiber areas and capillary density. One portion of the second sample was frozen and stored for determination of its oxygen consumption capacity. The other portion was frozen for analyses of selected enzyme activities such as: citrate synthase, creatinephosphokinase, myokinase, lactate dehydrogenase and phosphofructokinase.

Maximal oxygen uptake was determined, based on the levelling-off criterion, using a continuous protocol, increasing the work load every second minute on a cycle ergometer.

In order to establish the "lactate breaking point" or onset of blood lactate accumulation (OBLA), subjects performed exercise at selected work loads at the same occasion. The load was increased 25 watts every fourth minute until exhaustion. During the last minute of each interval oxygen consumption was measured and venous blood samples were collected. OBLA was defined as the intensity corresponding to a lactate concentration of 4 mmoles $\times l^{-1}$ blood (Fig. 1).

Some days later the same exercise was performed. However, when the pre-determined OBLA was reached and had been maintained for four minutes the experiment was stopped and a biopsy was obtained at termination (within 10 seconds) of exercise. Tissue samples were later analyzed for lactate concentration. Oxygen consumption was measured and blood samples (for lactate) were collected during the last minute of exercise.

Reporting to the laboratory for the final session, subjects performed a supramaximal short-term exercise. Load was set at 120% of maximal oxygen uptake and performed to exhaustion without any pre warm-up period. Failure to maintain a certain pedalling frequency (60 rpm $\times$ min^{-1}) was taken as an indication of exhaustion and maximum performance time. A biopsy (for lactate) was obtained immediately at termination of exercise. Following a recovery period of one minute a second biopsy was obtained.

In all sessions described above, local and central rate of perceived exertion (RPE) were monitored.

In agreement with earlier reports, muscle strength at high contraction velocities was found to correlate to the relative percentage of FT fibers. However, in contrast to these studies, muscle fatigue was not significantly related to the distribution of fiber types. Specific strength training, performed by some of the subjects, may have contributed to this finding. Thus, alterations in the activity level of some contractile and glycolytic enzymes may explain the deviating observation (under investigation). Factors linked to motor-unit activation and recruitment pattern must also be considered when discussing the altered fatigue-fiber type relationship. Subjects less susceptible to fatigue demonstrated the most pronounced recovery. Among individuals most susceptible to fatigue a wide range in terms of recovery from fatigue was evident. This variation may be explained by differences in activity of enzymes and concentration of substrates responsible for the alactacid part of anaerobic metabolism (under investigation). Since recovery from fatigue was found to correlate to "lactate release" to blood ($r = 0.60$), there are reasons to believe that intracellular accumulation of lactate or concomitant pH changes affect muscle contractility.

OBLA was found to occur at 65 (48-84) % of maximal oxygen uptake which corresponded to an oxygen need of 2.3 (1.8-3.1) $l \times min^{-1}$. OBLA was positively correlated to the relative area occupied by ST fibers ($r = 0.80$). Neither oxygen consumption nor ventilation differed when "OBLA" was repeated. Small individual variations (but not significantly different from the calculated 4 mmoles $\times$ l^{-1} blood level) for blood lactate were present at the repeated OBLA experiment. In contrast, muscle lactate concentration ranged 2.1-12.0 mmoles $\times$ kg^{-1} wet muscle. It can only be speculated whether this observation reflects individual patterns in terms of flux of lactate from the muscle cell.

Peak blood lactate during recovery post supramaximal exercise averaged 12.8 mmoles $\times$ l^{-1} blood. Time to exhaustion (performance time) ranged 65-212 seconds. Oxygen consumption 60 seconds after onset of exercise and time to peak oxygen consumption were related to capillary density (capillaries $\times$ mm^{-2})

of the vastus muscle. The data illustrate the importance of an efficient oxygen supply of the activated muscle for acute adaptation to the demands of a heavy work load.

Biochemical analyzes related to the study are ongoing.

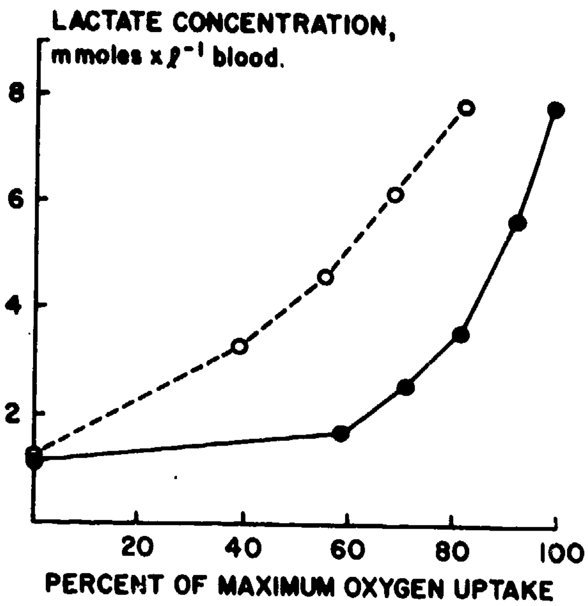

Figure 1. Onset of Blood Lactate Accumulation (OBLA) for Two Different Subjects.

Program Element: 6.11.02.A. DEFENSE RESEARCH SCIENCE, ARMY

Project: 3E161102B508. Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 009 Biological Processes that Limit Heavy Physical Work Ability of the Soldier

Study Title: Recruitment of Extrafusal Muscle Fibers during Exercise with Eccentric Contractions

Investigators: Howard G. Knuttgen, Ph.D., William J. Evans, Ph.D., John F. Patton, Ph.D. and Per Tesch, Ph.D.

Background:

Patterns of recruitment for skeletal muscle fibers (motor units) have been fairly extensively investigated for a variety of exercise conditions involving concentric and isometric muscle contractions (1, 2, 4). Virtually nothing is known about the patterns of fiber recruitment for exercise with eccentric contractions.

A person engages in a great amount of physical activity with eccentric muscle contractions during the course of each day. All effort of the work of lowering an object or the body, itself, depends on eccentric contractions. Each step in walking and running involves some eccentric contraction activity as the lead foot strikes the ground while walking downstairs is predominantly eccentric contraction exercise. Athletes are continuously employing eccentric contraction in preparation for the propulsive acts of jumping and throwing. Additionally, eccentric muscle contractions have been observed to be somewhat more effective in strength development than either concentric or isometric contractions (3). Such activity has been employed for years in the clinical setting for strength rehabilitation and the gymnasium for high-level strength devlopment on the basis of empirical observations.

The purpose of this study, therefore, is to determine: 1) the recruitment patterns among the different types of extrafusal muscle fibers during high-intensity exercise with eccentric contractions and 2) the effects of training on both the recruitment patterns and the accompanying metabolic events. In addition to obtaining information on the basic mechanisms of motor control, the results of this study should have practical application as regards training procedures for muscle strength and endurance in humans.

Progress:

This protocol requires the use of the high intensity cycle ergometer developed at this Institute for use in exercise using either concentric or eccentric muscular contractions (see Annual Progress Report FY 78; pp 133-137).

The ergometer has been mechanically and biologically calibrated for use in the reverse/accelerate mode (eccentric muscular contractions) throughout the range of exercise intensities to be employed. Subjects are, therefore, presently being recruited to participate in this eccentric training study.

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	009 Biological Processes that Limit Heavy Physical Work Ability of the Soldier
Study Title:	Anaerobic Power Production as a Component of Physical Fitness
Investigators:	Howard G. Knuttgen, Ph.D., John F. Patton, Ph.D. and James A. Vogel, Ph.D.

Background:

The physiological responses and adaptations to muscular exercise have been studied for some time. Numerous investigations have been published where the exercise engaged in, i.e., running, walking, cycling, is supported primarily by aerobic metabolism. Also considerable attention has been given to maximal voluntary contraction (MVC) of muscle groups and the development of strength. Relatively few studies involving anaerobic metbolism where rhythmic exercise is performed at very high intensities relative to MVC have been performed. The principle impediment to such studies has been the unavailability of ergometers that a) provide resistances adequate to cover all exercise intensities of which a person is capable and b) possess the feature of power production for the study of exercise both with concentric and eccentric muscle contractions.

Ergometers presently available for the study of human performance in cycling or cranking can produce conditions of exercise involving repetitive contractions approximating up to 20-30% of the MVC of the muscle groups involved (as measured in the concentric condition). Because of the increased capacity of the same musculature to produce force under eccentric conditions, the intensity range of these ergometers relative to eccentric MVC is even more limited. An ergometer was designed, therefore, to enable research involving exercise with both concentric and eccentric contractions at a full range of exercise, including the very highest intensities of which humans are capable under either condition.

Progress:

The ergometer designed and developed at this Institute for high intensity exercise has previously been described in detail (Annual Progress Report FY 78; pp 133-137). Experiments to provide both mechanical and biological calibration of the ergometer are still in progress. Biological calibration in both the concentric and eccentric modes was described in the 1979 Annual Progress Report (pages 151-154).

For mechanical calibration in the reverse/accelerate mode (eccentric exercise) functional resistance was provided over the flywheel. A range of resistances was applied to the flywheel while the torque potentiometer was changed to maintain a pedal axle RPM of 60. A linear relation was obtained between the resistance and the torque setting. The resistance in kg was then converted to a power term (watts) by knowing the flywheel circumference and geer ratio of flywheel to pedal revolution.

Mechanical calibration of the ergomerter in the forward/decelerate mode (concentric exercise) can not be accomplished using the above technique because of the decrease in motor speed and pedal axle RPM when in the torque mode. Therefore, a calibration dynamometer has been developed which will provide a mechanical evaluation of the torque and power that must be provided by the subject exercising in the concentric mode. An electric motor which is supported in a free-hanging fashion is fixed by a lever arm through a force transducer to the ergometer base. When this dynamometer provides the exact power to maintain the ergometer at a predetermined RPM, the torque recorded over the lever arm is then employed to calculate the power. In this way, the ergometer will be calibrated over the entire range of possibilities for intensity and velocity.

The calibration dynamometer has been built and is currently in the Institute. Once the base plate of the cycle ergometer is sufficiently stabilized to receive the dynamometer then the latter will be interfaced with the crank shaft of the ergometer and mechanical calibration will be performed.

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(010)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OC 6133	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	X YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61102A	3M161102BS10	CA	010
FORMER	6.11.02.A	3E161102BS08	00	010
c. XXXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code) (U)Structural and Functional Alterations in Cells, Tissues and Organs Induced by Exposure to Environmental Extremes (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 012900 Physiology; 010100 Microbiology; 003500 Clinical Medicine; 005900 Environmental Biology; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 05	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	7.0	229
	CURRENT 81	6.0	216

19. RESPONSIBLE DOD ORGANIZATION

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: HAMLET, Murray P., D.V.M.

NAME: DuBOSE, David A. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Hypothermia; (U)Reticuloendothelial; (U)Heatstroke; (U)Tolerance; (U)Hepatic Necrosis; (U)Isolated; (U)Perfused Rat Liver; (U)Endotoxin

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The objectives of this research are to develop and utilize adequate subcellular, cellular, organ, and whole animal models to clarify the mechanisms of pathological changes produced by environmental extremes of cold, heat, altitude and changes associated with physical fitness training. These studies apply disciplines of pathology to devise methods of prevention, prognosis and amelioration.

24. (U) The incidence and significance of endotoxin and gram-negative microbial invasion will be determined in the rat model of experimental heatstroke. The protective effect of endotoxin tolerance will be evaluated. The results may be applied to increasing man's resistance to the effects of heatstroke. Pathological changes in the liver are among the most consistent findings subsequent to heatstroke. The isolated perfused liver has proven to be a useful tool in determining the pathological effects of heat on this organ. The pathological effects of exposure to specified perfusing liquids at various temperatures will be monitored by enzyme leakage and light and electron microscopy. The value of hepatoprotective agents in ameliorating heat injury will be studied.

25. (U) 79 10 - 80 09 A significant incidence of endotoxin and gram-negative microbial duodenal invasion can be found in heat stressed rats. Of two rat groups, only one experience extra-intestinal invasion. No significant difference in length of survival between the groups was noted. Thus, invasion does not appear to play a significant role in rat death due to heatstroke. Considering all parameters measured, terminating liver perfusion experiments at differenct time intervals after perfusion at at 41°C, 42°C or 43°C indicated at least mild focal and probably reversible damage after 30-60 min. at 41°C, 30-45 min, at 42°C and 15-45 min. at 43°C. A sequence of events in heat-induced hepatic injury has been proposed.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 010 Structural and Functional Alterations in Cells, Tissues and Organs Induced by Exposure to Environmental Extremes

Study Title: Role and Significance of Endotoxin in Heatstroke

Investigator: David A. DuBose, M.S., Murray P. Hamlet, D.V.M., Lynn R. Trusal, CPT, MSC, Ph.D., Wilbert D. Bowers, Jr., Ph.D. and Roger W. Hubbard, Ph.D.

Background:

Endotoxins or lipopolysaccharides are complex substances associated with the cell wall of gram-negative microorganisms. A natural source or pool of gram-negative microorganisms and their endotoxins is the gastrointestinal tract of most mammals. The release of endotoxins into the circulating blood may ultimately lead to a state of shock (1). Endotoxin shock and heatstroke are similar in their clinical pictures (1,2). Circulating endotoxin is found in some cases of human heatstroke (3,4). Furthermore, treatment to reduce the pool of gut endotoxins is associated with an increased incidence of 18 hour survival in dog heatstroke (5). For these reasons, there has been an interest as to the role and significance of endotoxins in heat related deaths.

The Limulus amoebocyte lysate (LAL) test is an in vitro procedure which can indicate the presence of endotoxins in body tissues and fluids (6,7). This procedure and standard clinical microbiological methods were used to determine the incidence of endotoxin and gram-negative bacterial invasion in the rat model of experimental heatstroke (8).

Progress:

Since gram-negative bacteria were found in extra-intestinal tissues (liver, spleen and lung) of some non-heated controls of the first rat group studied, the experiments were repeated in rats free of extra-intestinal gram-negative bacteria (Group II). Rat extra-intestinal tissues were examined for enodotoxins and gram-negative bacteria, after heat stress injury. In addition, duodenal gram-negative bacterial count and LAL activity were determined. Two methods of tissue gram-negative bacterial isolation were used, direct and indirect. In direct isolation, 0.05 ml. of the homogenized tissue was inoculated on selective and non-selective plating media. In indirect isolation, 1 ml. of the homogenized tissue was first incubated in broth culture and then inoculated on plating media. These methods of isolation allowed for an estimation of the number of gram-negative bacteria in the tissues.

The data from group I rats can he found in Table 1. An examination of the non-heated controls revealed that the duodenum had both low gram-negative bacterial count and LAL activity. It also indicated that gram-negative bacteria and positive LAL tests could be found in tissues of apparently healthy asymptomatic rats. This was especially true for lung tissue. After heat stress, both short and intermediate survivors experienced a significantly increased incidence of duodenal invasion (gram-negative bacteria count $\geq 1.5 \times 10^4$/gram or LAL activity ≥ 50 ng of Escherichia coli endotoxin/gram). The incidence of duodenal invasion in rats sacrificed 72 hours after heat stress did not differ significantly from control values. A significant increase in the incidence of extra-intestinal invasion (gram-negative bacteria or endotoxins in the blood, liver or spleen) occurred only in the intermediate survival group. The incidence of gram-negative bacteria or endotoxins in the lung did not significantly change, after heat stress.

Most tissue isolates found in group I rats after heat stress were detected by indirect isolation (Table 1). Isolates found by the direct method were generally too few in number for accurate counting. Mean LAL activity in tissue and blood samples after heat stress (2.87 ng/g) was not significantly different from the activity noted in non-heated control rats (3.15 ng/g).

Figure 1 illustrates the relationship among signs of duodenal invasion, extra-intestinal invasion and length of survival after heat stress in group I rats. Lung invasion was not included in this comparison since it did not significantly change from control values (Table 1). The incidence of both duodenal and extra-intestinal invasion increased as length of survival increased. These indices of invasion decreased in rats sacrificed 72 hours after heat stress. Only the intermediate survivors had a significantly increased incidence of any sign of extra-intestinal invasion, as compared to controls. The incidence for multiple signs of extra-intestinal invasion was never significantly different from control values.

invasion in the second group of rats is reported in Table 2. No gram-negative bacteria were isolated from tissues or blood in non-heated controls, though some LAL activity was found. After heat stress, both short and intermediate survivors had a significantly increased incidence of duodenal invasion. Short survivors also had a significantly increased incidence of gram-negative bacteria in the lungs. Significant extra-intestinal invasion of the liver, spleen and blood was not noted in group II rats.

Table 3 compares the control and intermediate survival data of the two rat groups. Controls from group I had a significantly higher incidence of gram-negative bacteria and LAL activity in the lung. No significant differences in the incidence of high gram-negative bacterial count or LAL activity in the duodenum were noted between the two control groups. A comparison of the intermediate survivors indicated that there was no significant difference in the incidence of duodenal invasion, but group I had a significantly higher incidence of gram-negative bacteria in tissues and LAL activity in the spleen. Short and 72 hour survivors of groups I and II had no signficant differences in duodenal or extra-intestinal invasion.

A comparison of heat treatments and mean survival times of groups I and II can be found in Table 4. Heat treatments were similar except for a significantly greater total heat area of group I intermediate survivors. Attempts to obtain group II intermediate survivors with increased heat areas resulted in short survival. No significant differences in survival times were noted between the two groups.

The data from heat stressed group I rats appeared to indicate an association among duodenal invasion, length of survival and extra-intestinal invasion. However, multiple signs of extra-intestinal invasion were not significantly different from control values (Figure 1). Furthermore, the number of gram-negative bacteria in liver and spleen samples was considered low, since most isolates were found by indirect isolation and low counts were associated with most direct isolations. Significant endotoxemia was difficult to support for extra-intestinal LAL activity was not significantly different than the activity noted in controls. The lack of impact these findings had on heat stress survival was expressed by, no significant differences in the mean survival times of rat groups with (groups I) and without (group II) a significantly increased incidence of gram-negative bacteria or endotoxins in extra-intestinal test sites.

Heat stressed group II rats were free of tissue gram-negative bacteria prior to heating (Table 2). After heating, they had an increased incidence of invasion only in the duodenum and lung. The consistency between the two rat groups for signs of duodenal invasion may be due to multiplication of the low numbers of gram-negative bacteria normally present in this area or to the depositing of lower bowel gram-negative bacteria into the upper bowel. Isolates in the lungs of short survivors of group II rats may reflect the rats coprophagic nature and represent spread of gram-negative bacteria from the oral cavity into the lung during extreme heat stress.

In conclusion, heat stressed rats resulting in both short and intermediate survival experienced a significantly increased incidence of duodenal invasion. In children increased levels of gram-negatives in this area of the small intestine is reported to result in endotoxemia (9). Similar findings occurred only in intermediate survivors of group I rats, but appears to be associated with the animals health status prior to heating. The group I findings were significant in that even rats of a suspect health status did not suffer levels of gram-negative bacteria and endotoxins in extra-intestinal test sites which had significant impact on length of survival. Therefore, extra-intestinal invasion did not appear to have a major role in death in the rat model for experimental heatstroke.

These findings do not explain why heat stressed dogs pre-treated to reduce gut flora experienced a significantly increased incidence of 18 hour survival (5). Perhaps, this is due to species differences and reflects the rats natural resistance to endotoxin. The rat though has previously been used as a model to elucidate the role of gut-derived endotoxins in other disorders (10). Since heat area was not determined in the dog model, it is possible that differences in length of survival is due to significant differences in the heat treatment experienced by the pre-treated and non-treated dog groups. This may not be a complete explanation, for rat groups with similar mean rectal temperatures and significantly different mean total heat areas did not experience significantly different mean lengths of survival (Table 4). Therefore, the treatment to reduce gut flora (antibiotics, cathartics and enemas) may increase 18 hour survival by increasing hydration or protecting gut tissue from damage during heat stress. This possible reduction in damage may be due to the reduced exposure of gut tissue to endotoxins after heat stress. Perhaps, endotoxins associated with gut tissue after heat stress exert a direct cytotoxic effect which results in increased damage to these tissues. Thus, an increase in 18 hour survival rate may have resulted by reducing gut endotoxin levels. In the rat model, gram-negative bacteria and their endotoxins were found to increase in the duodenum after heat stress. The finding that reduction of gut flora increases 18 hour survival in dogs indicates that this noted duodenal invasion and the possible resulting direct cytotoxic effects of endotoxins on gut tissue may play a role in the pathophysiology of heat stress death.

The lack of support for extra intestinal invasion in the rat heatstroke model relates this model to hemorraghic shock models. In these models significant signs of extra-intestinal invasion is also not noted (11). Yet, animals made tolerant to endotoxin survive these forms of shock (11,12). This is explained by the reduced response of endotoxin-tolerant animals to endogenous catecholamines (11). Heat stress death may also be related to vasospasm of selected visceral areas. Resistance to vasoconstriction, such as found in animals made tolerant to endotoxins or catecholamines, may offer a form of prophylaxis to heat injury in the rat model for experimental heatstroke.

Publication:

DuBose, D. A., M. LeMaire, K. Basamania and J. Rowlands. Comparison of plasma extraction techniques in preparation of samples for endotoxin testing by the Limulus amoebocyte lysate test. J. Clin. Microbiol. 11:68-72, 1980.

Presentation:

DuBose, D. A., J. E. Rowlands and K. R. Basamania. The incidence of endotoxin and gram-negative microbial invasion in tissues and blood of rats subjected to heat stress. Federation of the American Societies for Experimental Biology, Anaheim, CA, 13-18 April 1980.

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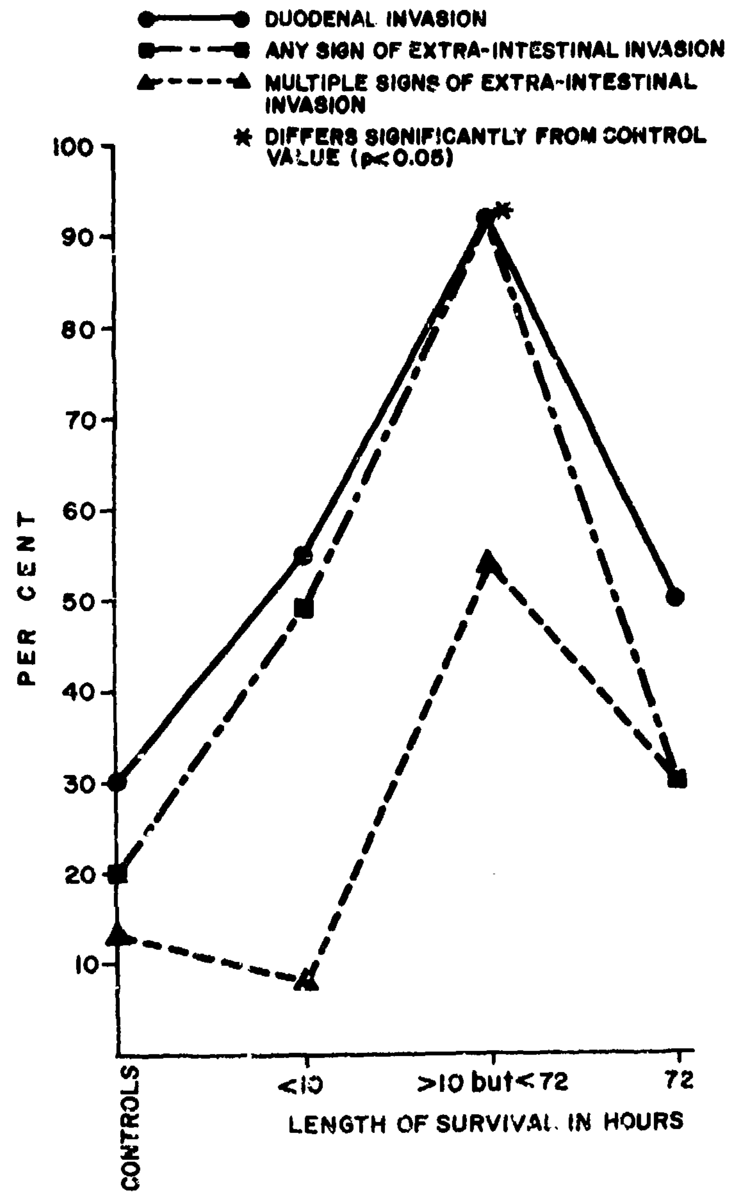

Figure 1. Relationship among duodenal invasion, extra-intestinal invasion and length of survival after heat stress in group I rats. Duodenal invasion: gram-negative bacterial count > 1.5×10^4 / gram or LAL activity > 50 ng of E. coli/gram. Any sign of extra-intestinal invasion: gram-negative bacterial isolates or positive LAL tests in any test site (blood, liver and spleen). Multiple signs of extra-intestinal invasion: gram-negative bacterial isolates or positive LAL tests in more than one test site.

Table 1. ENDOTOXIN AND GRAM-NEGATIVE BACTERIAL INVASION IN GROUP I RATS AFTER HEAT STRESS

	Duodenal[A] Bacterial Invasion	% with Gram-Negative Bacterial Isolates In: Lung D	Lung I	Liver D	Liver I	Spleen D	Spleen I	Blood	Duodenal[B] Endotoxin Invasion	% with Positive LAL Tests In: Lung	Liver	Spleen	Blood
Short Survivors	50.0*	38.5	64.3	18.4	37.1	14.3	30.0	7.7	47.1	55.7	13.2	15.0	6.3
< 10 h	N=20	N=14		N=38		N=21		N=13	N=17	N=14	N=38	N=20	N=32
Intermediate Survivors	83.3*	30.0	70.0	50.0*	61.5*	36.4	63.6*	40.0*	70.0*	50.0	28.6	36.4	45.6*
≥ 10 h but < 72 h	N=12	N=10		N=14		N=11		N=10	N=10	N=10	N=14	N=11	N=11
72 h Survivors	0.0	40.0	40.0	10.0	10.0	10.0	20.0	10.0	62.5	50.0	11.1	22.2	20.0
	N=8	N=5		N=10		N=10		N=10	N=8	N=[illegible]	N=9	N=9	N=10
Non-Heated Controls	7.1	20.0	40.0	4.7	20.0	6.6	13.3	0.0	30.0	42.9	12.5	13.3	3.4
	N=14	N=15		N=21		N=15		N=15	N=10	N=14	N=24	N=15	N=89

A = % with gram-negative bacterial count ≥ 1.5×10^4/gram
B = % with LAL activity > 50ng of *E. coli* endotoxin/gram
D = Direct isolation
I = Indirect isolation
LAL = Limulus Amebocyte Lysate
N = Number tested
* differs significantly from control value ($p < 0.05$)

Table 2. ENDOTOXIN AND GRAM-NEGATIVE BACTERIAL INVASION IN GROUP II RATS AFTER HEAT STRESS

	Duodenal[A] Microbial Invasion	% with Gram-Negative Microbial Isolates In: Lung D	Lung I	Liver D	Liver I	Spleen D	Spleen I	Blood	Duodenal[B] Endotoxin Invasion	% with Positive LAL Tests in: Lung	Liver	Spleen	Blood
Short Survivors	91.7*	33.3*	33.3*	0.0	0.0	0.0	0.0	14.3	33.3	33.3	0.0	0.0	16.7
< 10 h	N=12	N=12		N=12		N=12		N=7	N=12	N=12	N=12	N=12	N=12
Intermediate Survivors	40.0*	6.7	13.3	0.0	0.0	0.0	0.0	6.7	66.7	13.3	6.7	0.0	20.0
≥ 10 h but < 72 h	N=15	N=15		N=15		N=15		N=15	N=15	N=15	N=15	N=15	N=15
72 h Survivors	14.3	0.0	0.0	0.0	14.3	14.3	14.3	0.0	28.6	14.3	28.6	14.3	14.3
	N=7	N=7		N=7		N=7		N=7	N=7	N=7	N=7	N=7	N=7
Non-Heated Controls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	11.1	11.1	0.0	3.9
	N=18	N=56		N=18		N=18		N=18	N=18	N=18	N=18	N=18	N=18

A = % with gram-negative bacterial count ≥ 1.5×10^4/gram
B = % with LAL activity > 50ng of *E. coli* endotoxin/gram
D = Direct isolation
I = Indirect isolation
LAL = *Limulus* Amebocyte Lysate
N = Number tested
* differs significantly from control value ($p < 0.05$)

Table 3. COMPARISON OF ENDOTOXIN AND GRAM-NEGATIVE BACTERIAL INVASION IN INTERMEDIATE SURVIVORS AND CONTROLS OF RAT GROUPS I & II

	Duodenal[A] Bacterial Invasion	% with Gram-Negative Bacterial Isolates In: Lung D	Lung I	Liver D	Liver I	Spleen D	Spleen I	Blood	Duodenal[B] Endotoxin Invasion	% with Positive LAL Tests In: Lung	Liver	Spleen	Blood
Intermediate Survivors													
Group I	81.8	30.0	70.0*	50.0*	61.5*	36.4*	63.6*	40.0	70.0	50.0	28.6	36.4*	45.6
Group II	40.0	6.7	13.3	0.0	0.0	0.0	0.0	6.7	66.7	13.3	6.7	0.0	20.0
Controls													
Group I	7.1	20.0*	40.0*	4.8	20.0	6.6	13.3	0.0	30.0	42.8*	12.5	13.3	3.4
Group II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.0	7.1	11.1	0.0	3.9

A = % with gram-negative bacterial count $\geq 1.5 \times 10^4$/gram
B = % with LAL Activity > 50ng of E. coli endotoxin/gram
D = Direct isolation
I = Indirect isolation
LAL = *Limulus* Amebocyte Lysate

*significant difference between groups I & II ($p < 0.0?$)

TABLE 4

COMPARISON OF HEAT TREATMENTS AND MEAN SURVIVAL TIMES IN RAT GROUPS I & II

		Mean Max‡ Temp. in Degrees C	Mean Total‡ Heat Area in Degree-Mins.	Mean Survival Length In Hours
Short Survivors	Group I	42.42 ± 0.28	82.78 ± 24.56	2.88 ± 2.38
	Group II	42.41 ± 0.14	78.81 ± 18.85	2.25 ± 1.48
Intermediate Survivors	Group I	42.31 ± 0.20	54.71* ± 10.80	19.00 ± 4.24
	Group II	42.26 ± 0.13	37.92 ± 5.52	20.66 ± 8.21
72 Hour Survivors	Group I	42.14 ± 0.27	52.85 ± 6.40	* *
	Group II	42.00 ± 0.27	47.04 ± 18.24	* *

‡ = values are means ± standard deviation
* = significant difference between groups I & II ($p < 0.05$)
* * = animals sacrificed 72 hours after heat stress

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	010 Structural and Functional Alterations in Cells, Tissues and Organs Induced by Exposure to Environmental Extremes
Study Title:	Effects of Heat on the Structure and Function of the Perfused Rat Liver
Investigators:	Wilbert D. Bowers, Jr., Ph.D., Roger W. Hubbard, Ph.D., Murray P. Hamlet, D.V.M. and John T. Maher, Ph.D.

Background:

The potential for conflict in relatively hot areas continues to stimulate interest in heatstroke and heat induced injury. Research at this Institute (3,7) and work in other laboratories (1, 2, 4-6, 8,-12) have implicated hepatic damage in the sequelae of heat injury. The objectives of this research were to: develop an in vitro system to monitor the effects of heat alone, independent of complexities such as cardiovascular function, hormones and heat induced products; determine at what temperatures metabolic, histological and ultrastructural changes occur in the perfused liver; characterize the time/temperature relationships in a simple system where many of the variables could be controlled; and establish a sequence of events in the progression of heat injury to the liver. Our previous reports indicated that the perfused liver can be severely damaged after exposure to 41, 42 or 43°C for 90 minutes, and that enzyme leakage and bile production were usually affected at shorter time intervals. This was evident in previous descriptions of the 90 minute groups and the 43°C time interval groups. This report describes data obtained when the perfusions were terminated at time intervals of 90 minutes or less at 41 and 42°C and presents the light and electron micrographs for the time interval at which injury was first observed. Structural data for 43°C are included. In previous discussions structural characteristics typical for the groups were described. In this report, the numbers of individual livers showing even mild focal structural damage are reported.

Progress:

In these liver perfusion experiments, the rate of bile production decreased between 30 and 45 minutes at 41°C (Figure 1-A, B, C and D) while low but increasing levels of enzymes were usually evident in the perfusate exiting these livers between 30 and 60 minutes. The similarity between Figures 1-A, B, C and D reflect the reproducibility of the data since each graph represents eight different liver perfusions (32 livers for this figure). Light microscopy (Figure 2) and electron microscopy (Figure 3) indicated normal structure for 7 of 8 livers at 45 minutes; however, structural parameters indicated focal injury in 7 of 8 livers after 60 minutes at 41°C (Figures 4 and 5). At 42°C, most parameters indicated damage occurred between 30 and 45 minutes (Figure 6). Light and electron microscopy showed normal structure at 15 minutes (Figures 7 and 8). Focal structural damage was present in 3 of 8 livers exposed to 42C for 30 minutes (Figure 9), and 8 of 8 livers showed structural damage after 45 minutes (Figures 10 and 11). It should be noted that perinuclear vacuolization can occur as a fixation artefact in the light microscopic preparations of the 15 and 30 minute perfusions. This was avoided by initial fixation with the standard neutral buffered formalin diluted 1/100 and increasing the concentration to a standard solution over a 2 hour period.

At 43°C, half the livers showed normal structure after 15 minutes (Figure 12) while others showed small areas of focal hepatocellular damage (Figures 13 and 14). This damage increased in frequency and severity with time. Thus, in general terms, mild focal hepatocellular injury occurred at 30-60 minutes at 41°C, 30-45 minutes at 42°C and 15-45 minutes at 43°C. The increase in frequency and severity of hepatic damage, with both time and temperature, support the hypothesis that heat injury results in a continuum of events leading to irreversible hepatic necrosis. The presence of flocculent densities in mitochondria (Figure 11) related to other indicators of irreversible injury to the cells in which they were found. The presence of these densities was diffuse at the longer time intervals and higher temperatures; however, such cells were often isolated among other cells which appeared normal when the heat load was low. In these cases, the livers as units were probably viable and capable of repairing focal damage under normal circumstances.

Considering all of the data obtained in this laboratory by heating perfused livers, the following sequence of events is proposed for the pathogenesis of heat-induced hepatic injury. First, mild elevations in temperature stimulate metabolic processes such as release of bile and hydrolysis of glycogen. Endothelial cells are subjected to hyperthermia and sinusoidal lining cells are fragmented leaving denuded sinusoids which often fill with cellular debris. This is followed by injury to hepatocyte membranes resulting in enzyme leakage and hydropic changes. Vacuolization, loss of microvilli, and, in many instances, fragmentation of hepatocytes occur. Concurrent with these changes is evidence of irreversible mitochondrial damage. Dissociation of hepatocytes may occur subsequent to vacuolization. This dissociation of hepatocytes may be more characteristic of isolated perfused livers with severe heat exposure since it was rarely observed in vivo. It is also possible that, in vivo, other heat induced phenomena result in death prior to reaching this level of heat exposure. In support of the latter possibility, Hubbard et al. (13) calculated the time at rectal temperature above 40.4°C in degree-minutes and related this to percent survival for rats. When this concept was applied to liver exposure, ninety minutes at 42°C represented 144 deg-min. for isolated livers. This exceeds the 90 deg-min exposure which results in a 100% fatality rate for sedentary heated rats.

The sequence of these events is consistent and their occurrence has been documented in human heatstroke, but at a given temperature, the time in which they occur may vary.

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Publication:

Bowers, W. D., Jr. R. Hubbard, D. Wagner, P. Chisholm, M. Murphy, I. Leav, M. Hamlet, and J. Maher. The integrity of perfused rat liver at different heat loads. Lab. Invest. (In press).

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Explanation of Figures

Figure 1. Graph showing bile production and release of alanine aminotranferase (GPT) and aspartate aminotransferase (GOT) into the perfusates for experiments at 41°C which were terminated after 45 minutes (A), 60 minutes (B), 75 minutes (C) and 90 minutes (D). Vertical scales indicate international units of enzyme/liter (left) and ml of bile (right). Horizontal scales indicate sample time. Comparing points on A, B, C and D for a specific parameter at a given time indicates reproducibility for experiments of 8 livers each or a total of 32 perfusions.

Figure 2. Light micrograph showing typical structure of livers perfused for 45 minutes at 41°C is normal.

Figure 3. Electron micrograph showing normal tissue after 45 min. at 41°C.

Figure 4. Light micrograph showing mild periportal necrosis after 60 minutes at 41°C.

Figure 5. Electron micrograph showing typical heat-induced changes (no endothelium, few microvilli, cellular debris in sinusoids) after 60 minutes at 41°C.

Figure 6. Graph showing bile production and release of GPT and GOT into the perfusate for experiments at 42°C which were terminated after 15 minutes (A), 30 minutes (B), 45 minutes (C), 60 minutes (D) and 75 minutes (E) and 90 minutes (F).

Figure 7. Light micrograph of liver perfused at 42°C for 15 minutes. Structure is normal.

Figure 8. Electron micrograph of liver perfused at 42°C for 15 minutes. Ultrastructure is normal.

Figure 9. Light micrograph of liver perfused at 42°C for 30 minutes. Mild centrilobular damage is evident. Periportal changes were also evident. Changes were present in 3 of 8 livers.

Figure 10. Light micrograph of livers perfused at 42°C for 45 minutes. For this group 8 of 8 livers showed damage.

Figure 11. Electron micrograph of liver perfused at 42°C for 45 minutes. Typical heat-induced ultrastructural changes were evident (vacuolization, loss of microvilli and presence of flocculent dense bodies).

Figure 12. Light micrograph of liver perfused at 43°C for 15 minutes. Structure is essentially normal in most tissue; however, some mild focal changes were present.

Figure 13. Light micrograph of liver perfused at 43°C for 15 minutes showing centrilobular vacuolization.

Figure 14. Electron micrograph showing focal ultrastructural changes at 43°C after 15 minutes.

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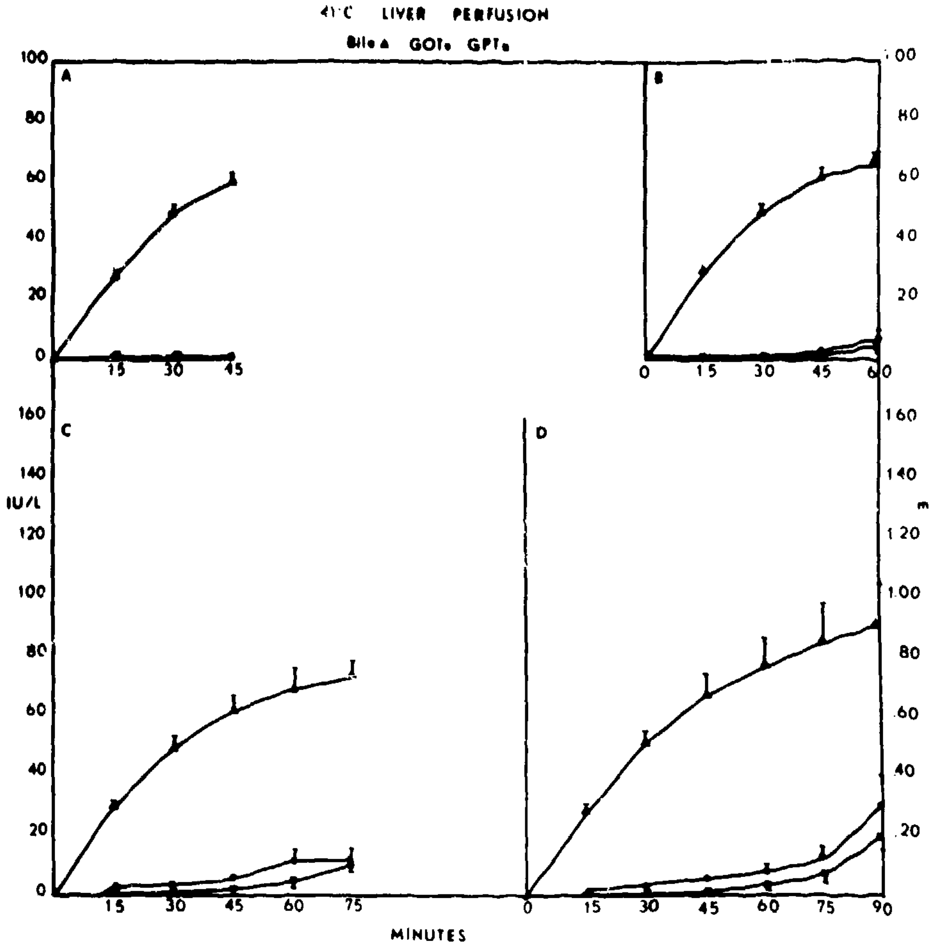
41°C LIVER PERFUSION
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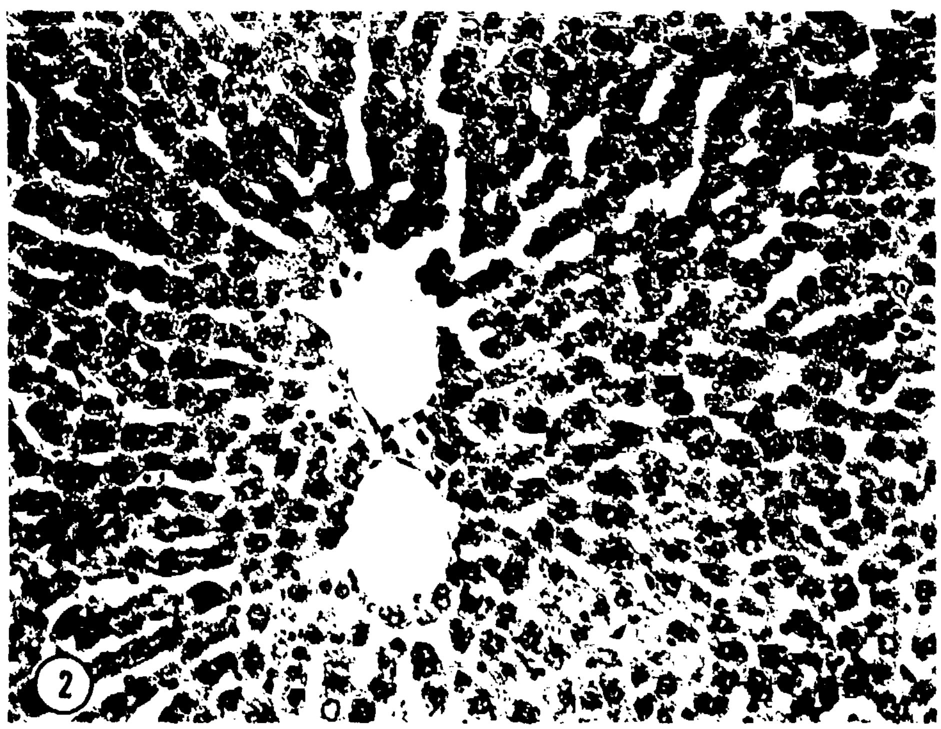
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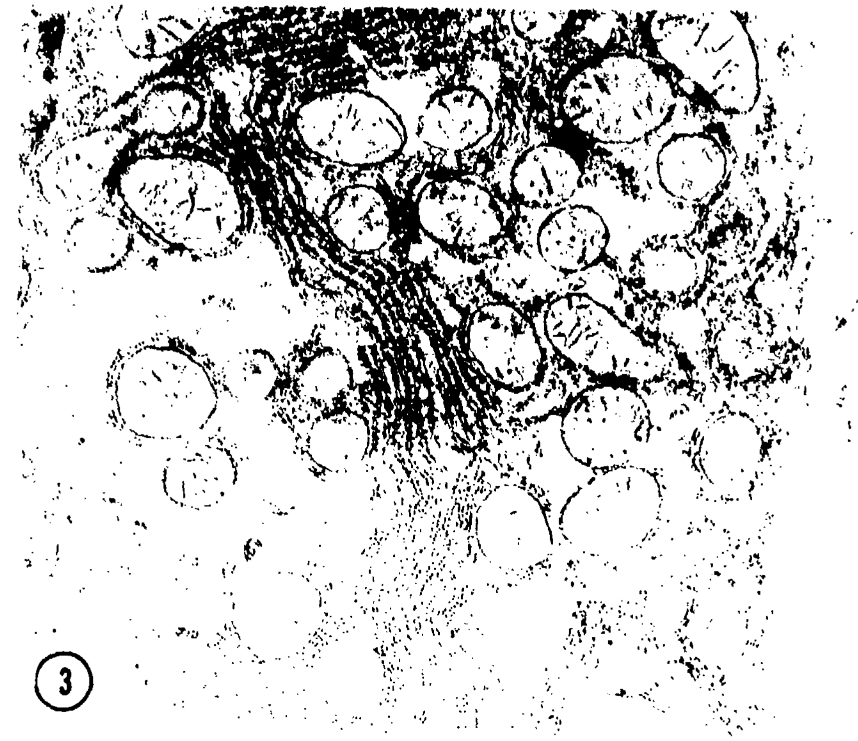
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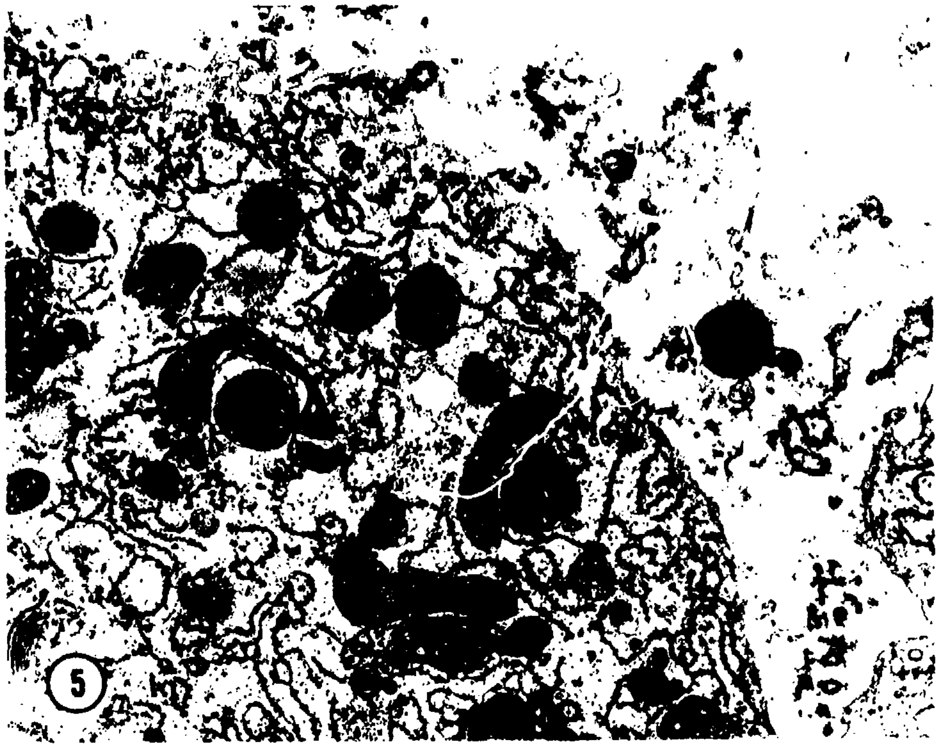

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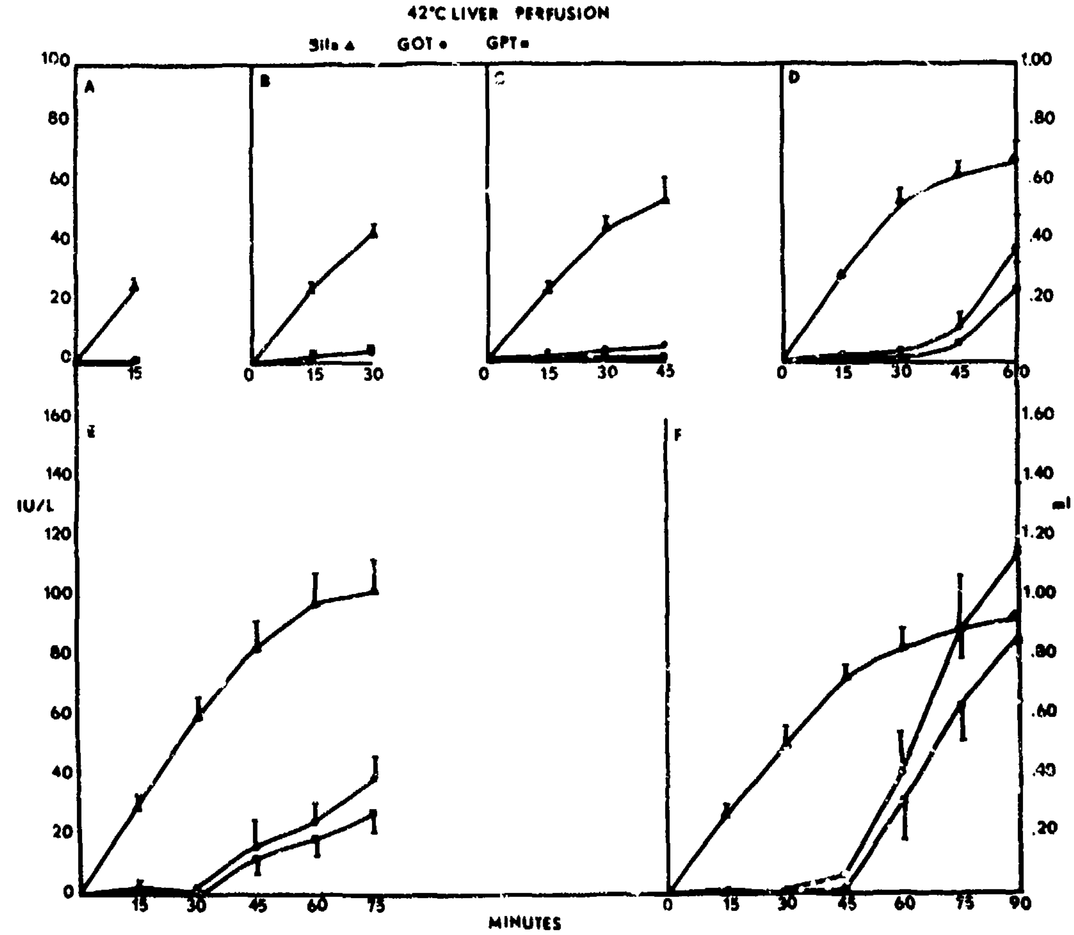

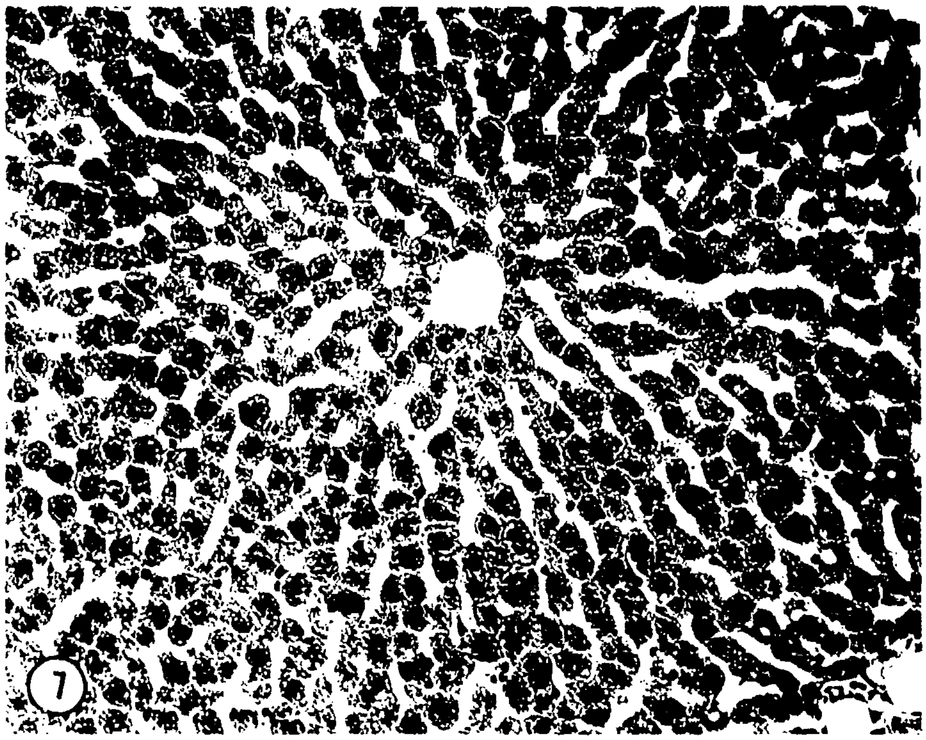
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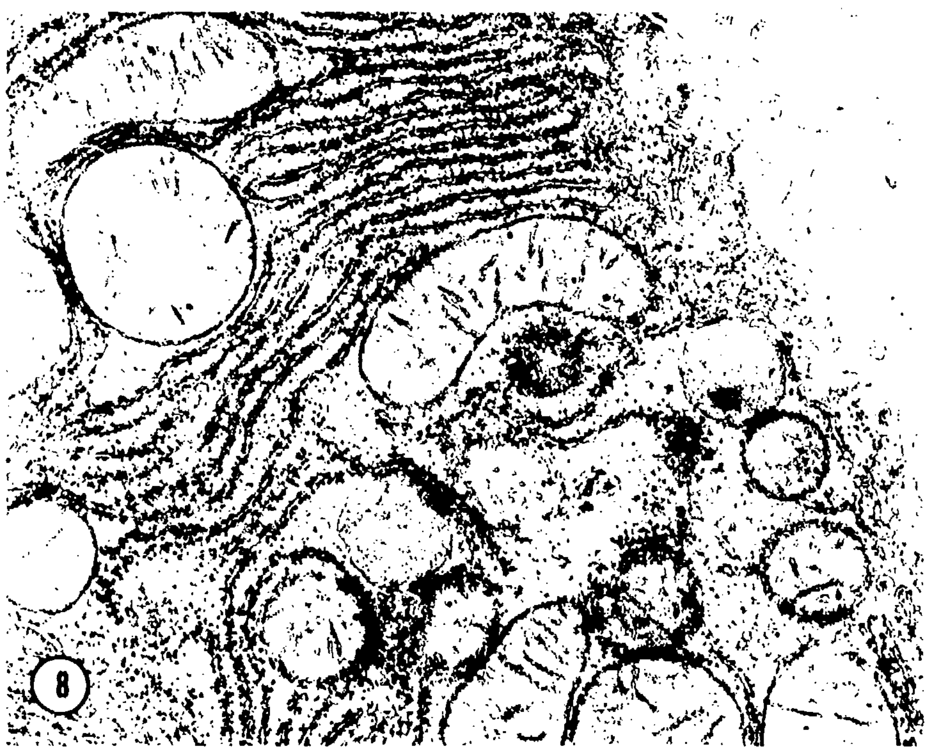
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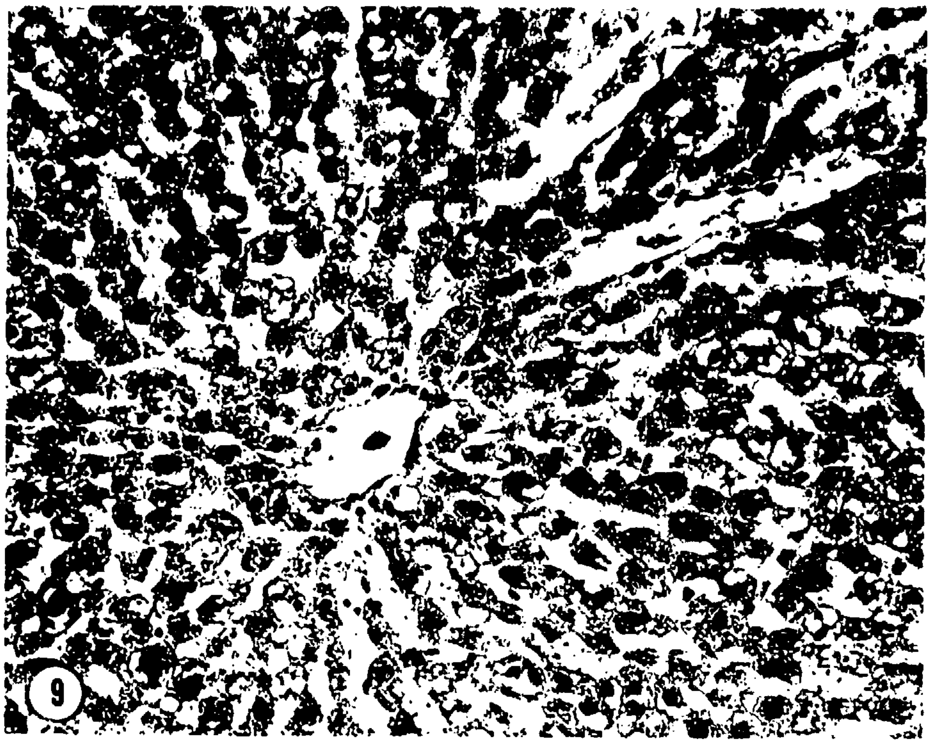

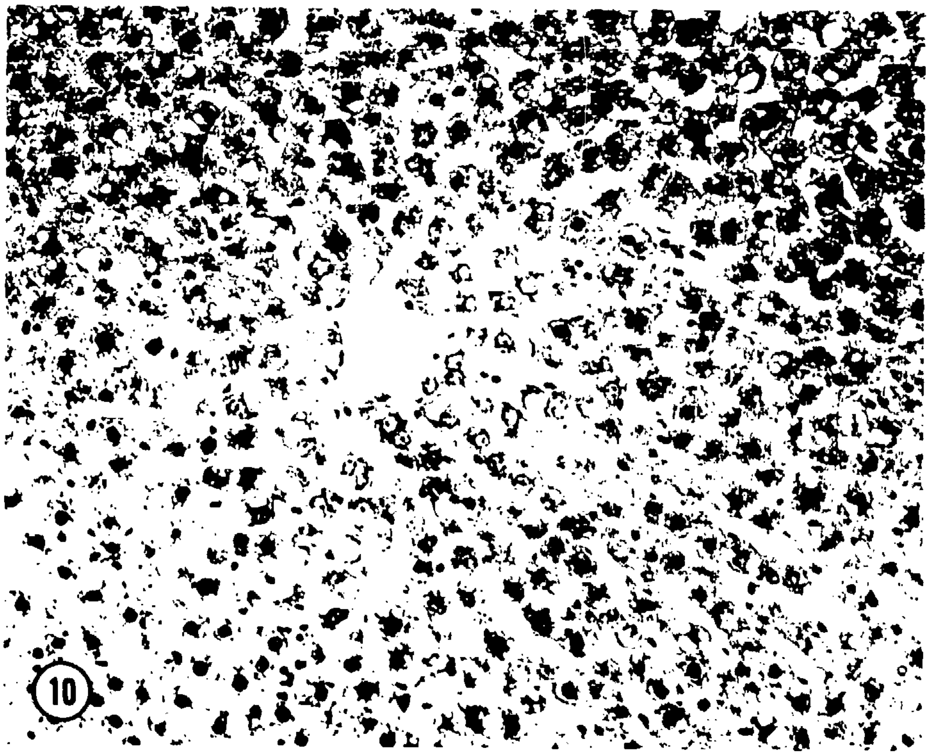

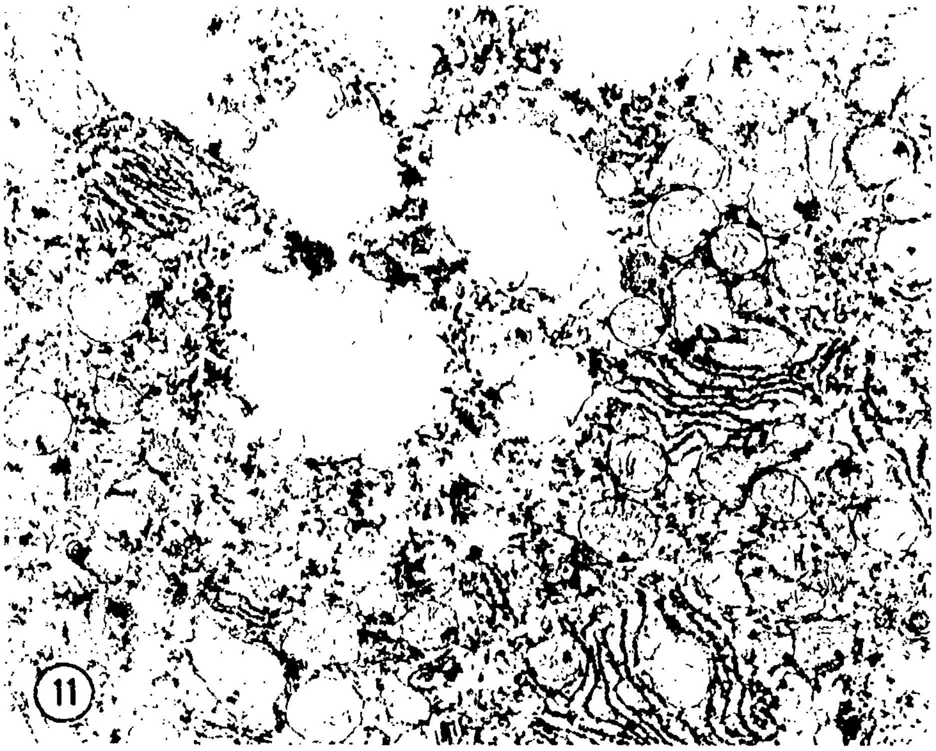
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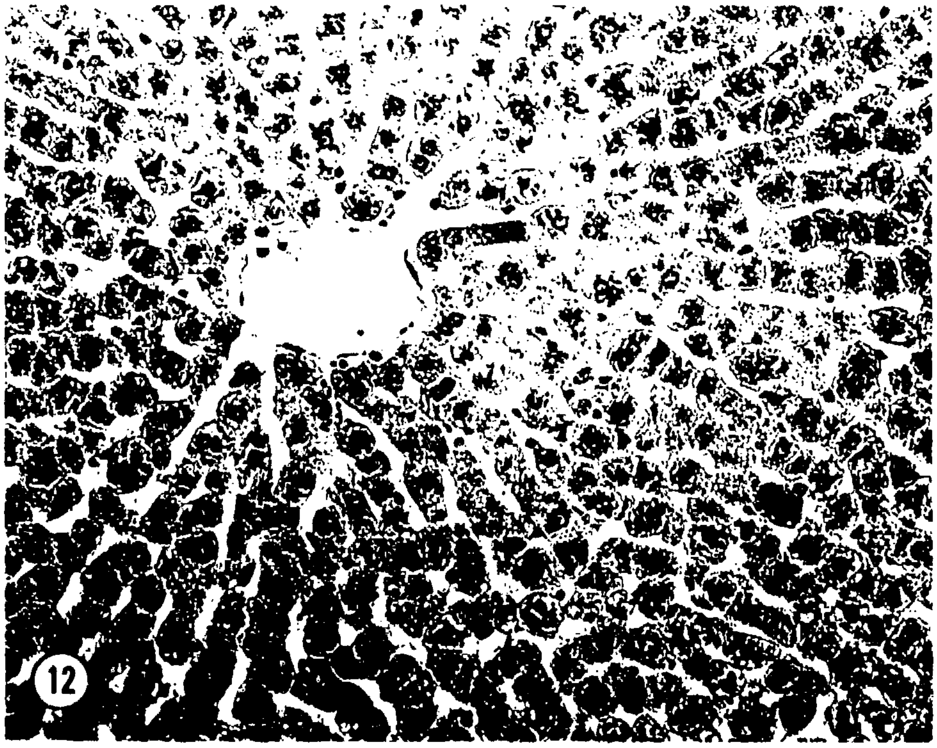
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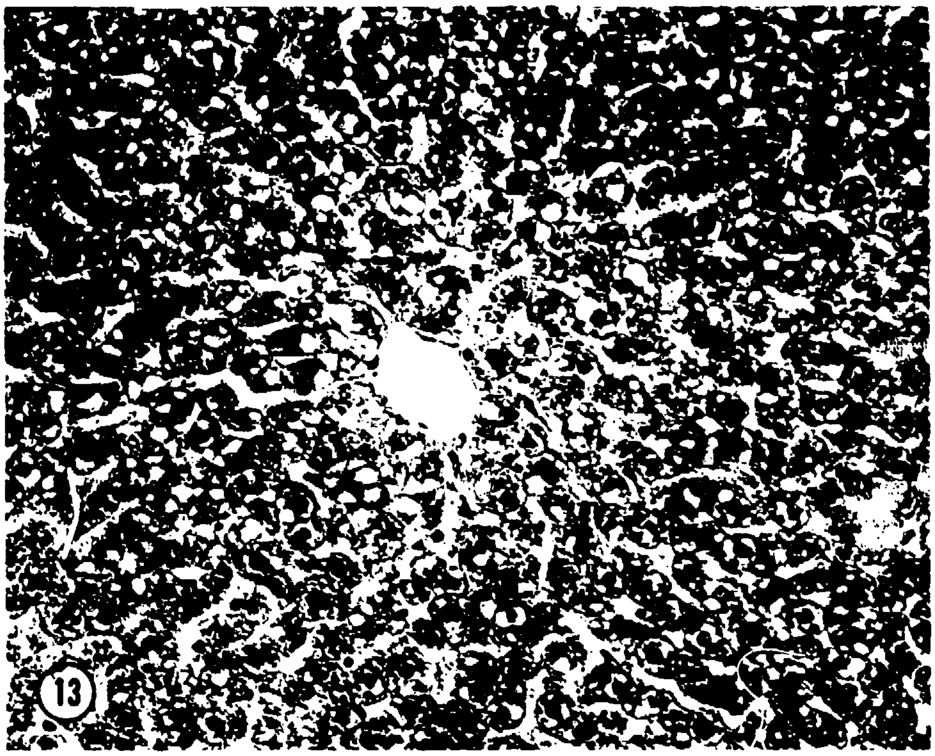
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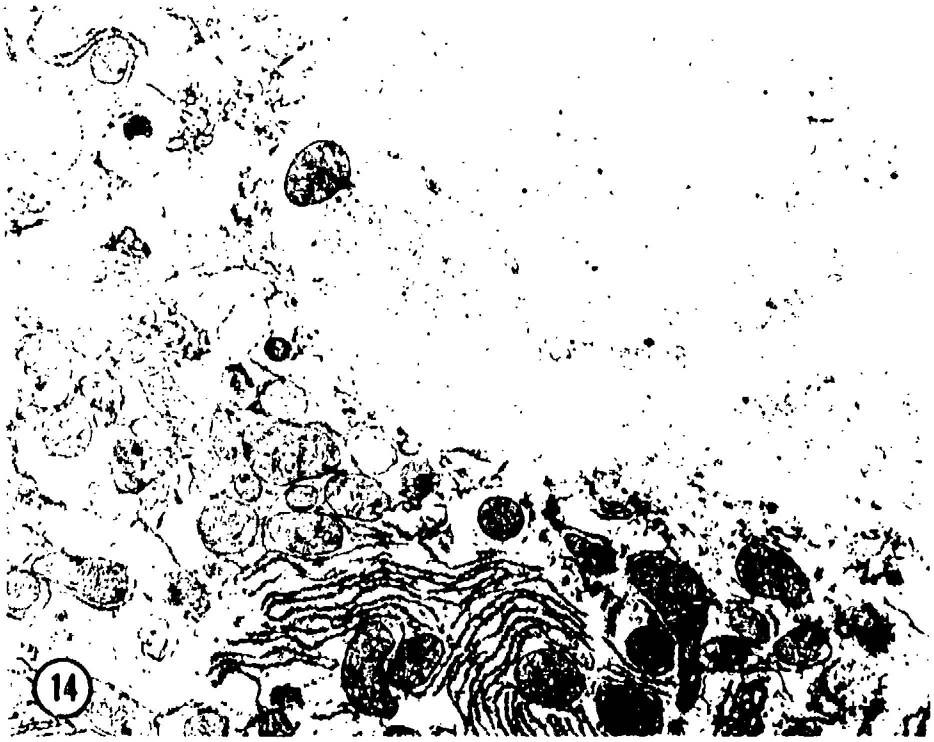
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(011)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY			1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
			DA OC 6122	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61101A	3M161102BS10	CA	011
b. FORMER	6.11.02.A	3E161102BS08	00	011
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)*
(U) Assessment of the Impact of the Environment on Military Performance (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 013400 Psychology; 005900 Environmental Biology; 002300 Biochemistry; 012900 Physiology Stress

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 11	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:*
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	4.0	180
	CURRENT 81	5.0	146

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: PEARLMAN, ELIOT J., LTC, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* KOBRICK, John L., Ph.D.
TELEPHONE: 955-2855
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: FINE, Bernard J., Ph.D.
NAME: STOKES, James W., LTC, MC DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Human Performance in Heat; (U)Human Performance in Cold; (U)Human Performance at Altitude; (U)Sustained Human Performance

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Operational planning, personnel selection and training, new equipment design and computer simulations used in doctrine and force development require data on how environmental conditions affect individual operator capabilities. This work unit assesses at the level of basic functions the psychological and psychophysiological disruption caused by thermal stress, hypoxia and fatigue which can impair critical military performance before the soldier becomes an environmental casualty.

24. (U) Psychological tests and performance tasks are used under controlled conditions in the field and laboratory to quantify decrements in perceptual, cognitive and psychomotor functions of special relevnce to the Army. Psychological inventories provide a basis for predicting individuals whose performance is especially susceptible to stress, while psychophysiological measures are used to examine mechanisms underlying the decrements.

25. (U) 79 10 - 80 09 Findings regarding individual differences in color discrimination and improvement of this ability with repeated testing were presented and published. The accuracy of judgments of distance to a military target at various locations on actual terrain were compared with judgments by the same observers (inexperienced, or experienced artillerymen) from projected slides of the same scene. Although group average judgments were accurate for both actual terrain and slides, individual performances were widely divergent. Analyses of this variability and its implications for use of projected slide simulations and for selection and training of personnel for performance, in adverse environments were presented. A CRT compensatory tracking task of proven sensitivity to hypoxic stress was augmented with a detection/reaction time (secondary) task for use as a general performance battery in laboratory and field environmental studies. A protocol was written for a collaborative study (with LAIR) of the effects of levels of hypoxia on dark adaptation, accommodation and night vision, scheduled for Nov-Dec '80.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	011 Assessment of the Impact of the Environment on Military Performance
Study Title:	The Effect of Repeated Measurements and Reduced Illumination on Performance of the Farnsworth-Munsell 100 Hue Test
Investigators:	Bernard J. Fine, Ph.D. and John L. Kobrick, Ph.D

Background:

The ability to discriminate colors has a seemingly important but as yet undefined relationship with certain military tasks, e.g. contour map reading, target detection and identification, distance estimation. Relatively little is known about the effect of environmental stresses on color discrimination or of the differences between individuals in their ability to discriminate colors.

Two significant findings in our previous research have led to the present study. One study (Fine, 1973) found extremely large differences in color discrimination ability between Subjects (Ss) selected as extreme on the personality dimension of field-dependence-independence; field-independent (abstract) Ss were better color discriminators than were field-dependent (concrete) Ss on the Farnsworth-Munsell 100-Hue test (F-M test), a widely used test of color vision. A second study (Fine & Kobrick, unpublished data, 1976), in which the F-M test was administered 10 times to soldiers undergoing environmental stress, showed a signficant improvement in performance over five of the first six trials which were conducted under non-stressful conditions. The Ss in this study were predominately from the middle of the field-dependence distribution so that personality differences in performance could not be assessed.

The present study was designed to validate the results of the two preceding studies since those results have important implications for using the F-M test in situations requiring repeated assessment of color discrimination and assessment of individual differences in performance.

Thirty-six soldiers (11 field-independent; 10 field-central and 15 field-dependent) were administered the F-M test twice a day for five consecutive days. For all Ss, trials 1-5, 8 and 10 were under 100 watt illumination and trials 6, 7 and 9 were under either 60 watt, 40 watt or 25 watt illumination according to a random procedure. The low illumination conditions were included to provide data for use in studies requiring color discrimination under poor illumination such as at dawn or dusk.

Progress:

The study has been completed. Both previous studies were validated; field-independent persons were shown to be significantly better color discriminators than were field-dependent persons and performance on the F-M test continued to improve over the 10 trials. The 25 watt condition was found to be significantly poorer than both the 40 and 60 watt conditions which were not distinguishable from one another.

The results have important implications for the use of the F-M test in stress studies requiring multiple administrations of it, since the effects of stress may be confounded with the continued improvement in performance on the test. The results also bear on the prediction and understanding of individual differences in performance of tasks which require color vision for their accomplishment.

Presentation:

Fine, B. J. Field-dependence and the discrimination of colors: military implications and applications, paper presented at the annual meeting of the American Psychological Association, Montreal Canada, 3 September 1980.

Publication:

Fine, B. J. and Kobrick, J. L. Field-dependence, practice and low illumination as related to the Farnsworth-Munsell 100-Hue Test, Percept. Mot. Skills, (In press).

LITERATURE CITED

Fine, B.J. Field-dependence and "sensitivity" of the nervous system: supportive evidence with color and weight discrimination. Percept. Mot. Skills, 37, 287-295, 1973.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	011 Assessment of the Impact of the Environment on Military Performance
Study Title:	Comparison of Distance Estimation Accuracy Between Real-World Scenes and Color Slide Representations of Them
Investigators:	John L. Kobrick, Ph.D. and Bernard J. Fine, Ph.D

Background:

The artillery forward observer (FO) is the most critical element in the guidance system for the field artillery. He is also the individual most vulnerable to environmental stress, since he performs his mission in an unprotected outdoor environment. One of the FO's major tasks is making accurate distance estimations from his own position to targets, known reference points, and exploding rounds. Artillery operational standards set the maximum acceptable error in target location at 250 meters, regardless of target distance from the observer. However, Army field tests have shown typical FO errors of 500 to 700 meters, despite training (1-3), and have noted a large range of individual differences among separate FO performances.

Previous research has shown significant impairment of artillery fire direction center tasks due to environmental stress. Such exposure might also be expected to influence FO performance, and, of most interest, distance judgment. Accurate study of such effects under controlled environmental conditions requires the use of climatic chambers in which FO tasks must be simulated, usually by two-dimensional displays such as projected slides of target scenes. The purpose of this project was to determine whether actual distance judgments in the tri-dimensional real world correspond to distance judgments by the same individuals made to targets in the same scenes represented by two-dimensional slide projections. This validation study is essential to determine whether two-dimensional simulation techniques can be used in climatic chamber studies of the effects of environmental stress on distance judgment and related FO performance.

Progress:

The following study was conducted to compare distance judgments made in an outdoor real world situation with those made by the same observers to equivalent slide projections. The subjects were 16 soldier volunteers with no previous training in judging distance, and 10 officers and NCOs who had some previous service as FOs.

Field viewing tests were conducted on a large grassy area against a distant background of low hills and trees. The target was an Army 2-1/2 ton truck, which was shown parked broadside to the subjects in a series of 20 positions ranging in distance from 600 to 1550 meters in increments of 50 meters. Two complete series of the 20 target positions were presented, each series occurring in a different randomized order. Subjects judged independently and with unaided vision the apparent distance to the target in each trial. No information of any kind was ever given to the subjects regarding the actual target distances involved.

Photographic slides were made of the target in each position at the moment of judgment. These were shown to the subjects in another session approximately four weeks later as projected views from which they estimated again the apparent distances to the target. The projected scenes were presented so as to duplicate the real world image sizes at the eye which the target would subtend at the actual object distances involved. Two complete series of the 20 slides were presented in different random orders. The subjects were also tested for visual acuity, depth perception, phoria, and color sense, and on a measure of field-dependence.

The basic datum used for analysis of the results was the individual subject estimate of target distance at each target position, expressed in meters. A treatments x subjects analysis of variance was conducted first, including tests for the effects of target distance (D), test sequence (TS), and field viewing vs. slide-viewing (FS). A highly significant main effect was found for D ($F=59.75$, $df=19,96$, $P<.001$), and for the DxFS interaction ($F=3.32$, $df=19,96$, $P<.001$). No other effects reached statistical significance.

In order to examine possible internal relationships and trends in the data not revealed by the analysis of variance, a number of graphic plots were then performed. The group means of the individual distance estimates for field viewing were plotted first as a function of the true distances involved. These are shown in Figure 1.

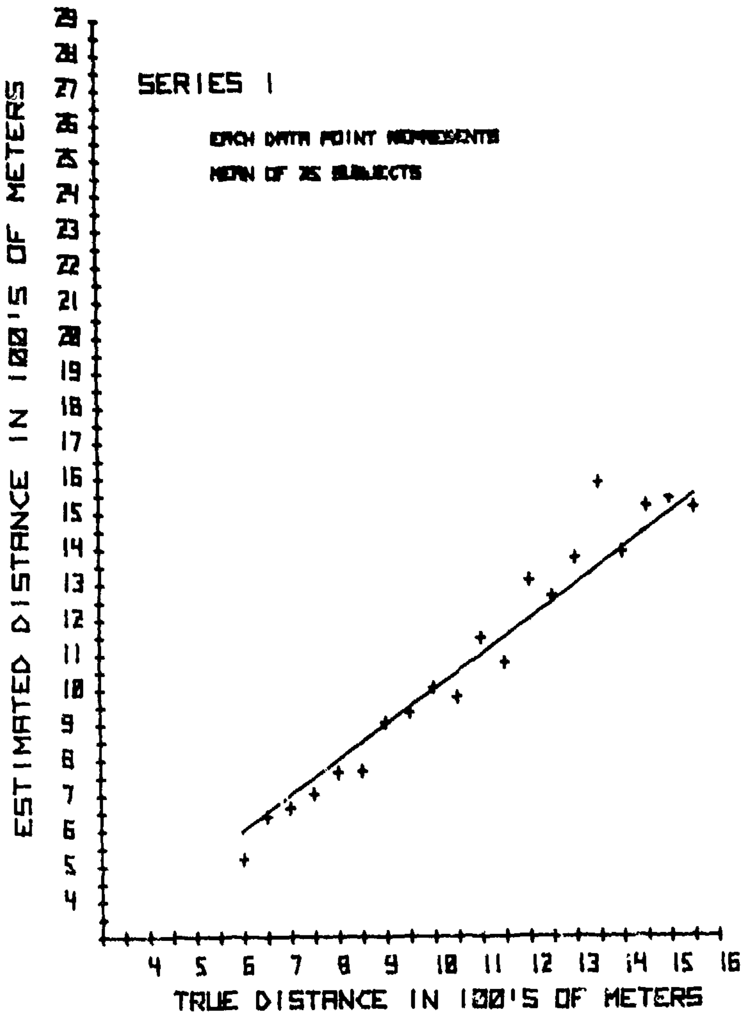

Figure 1. Group mean distance estimations for the various target positions

On the basis of Figure 1, one would conclude that the group as a whole judged the various distances of the target very accurately. In fact, the group means at all distances were within the 250-meter error artillery operational tolerance. However, when the individual distance estimations for all subjects were plotted separately for each respective distance, a totally different picture emerged. Figure 2 shows the individual plots for all subjects for the series of 20 judgments.

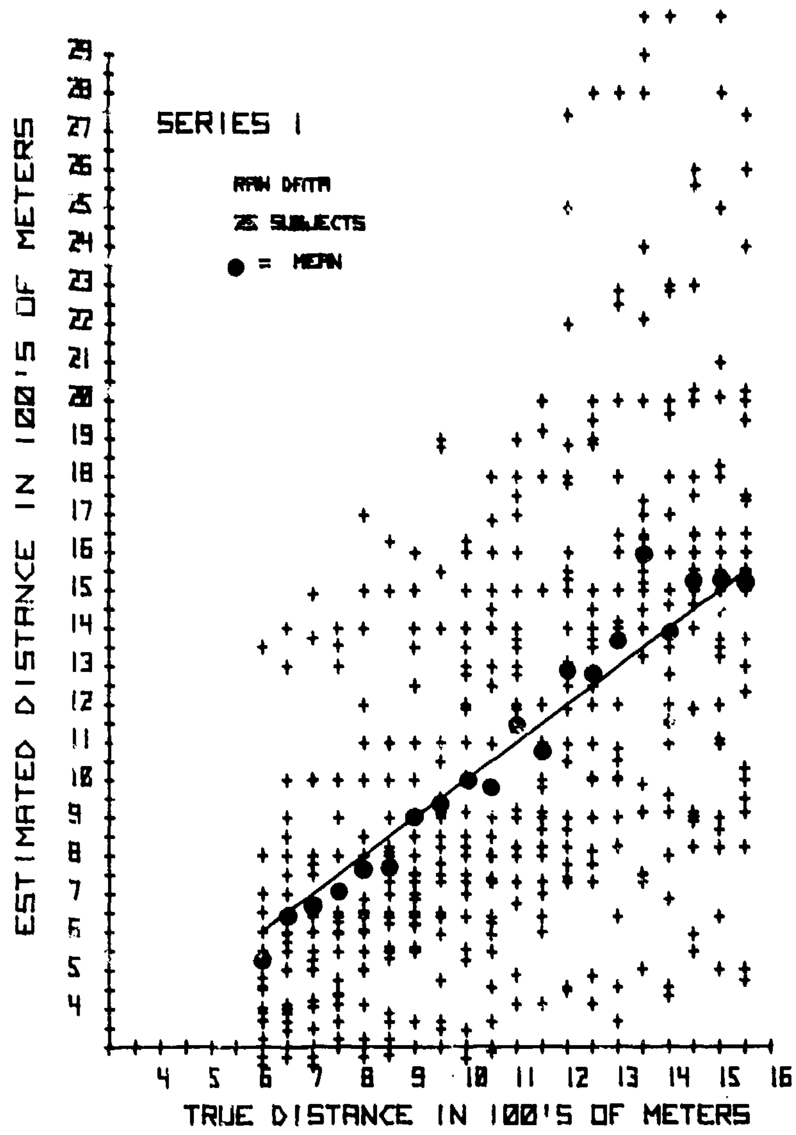

Figure 2. Individual distance estimations and group averages for the various target positions.

It can be seen that subjects varied widely in their estimates at all target positions, so much so that values overlapped for almost the entire range of object distances. In fact, 55% of the individual judgments were outside the 250-meter tolerance. The average error for all subjects for all judgments was 381 meters. It should be pointed out that this value is remarkably close to the average error of 382 errors for the Fort Sill students in the WSTEA-FO study (3).

Clearly, the group means shown in Figure 1 only superficially represent the true performance of the group, and are of little specific use in typifying the range of performance encompassed by the group. Separate plots of the data for each subject for each of the two series, however, showed that their judgments, though frequently erratic and inaccurate, were remarkably reliable when one considers that the series were presented in two different random orders. In fact, the correlation coefficient between the two series for all subjects was $r = .89$ ($P < .001$).

The field viewing data were then plotted separately for the experienced and inexperienced observer groups. The group mean estimation values for each subgroup are shown in Figure 3.

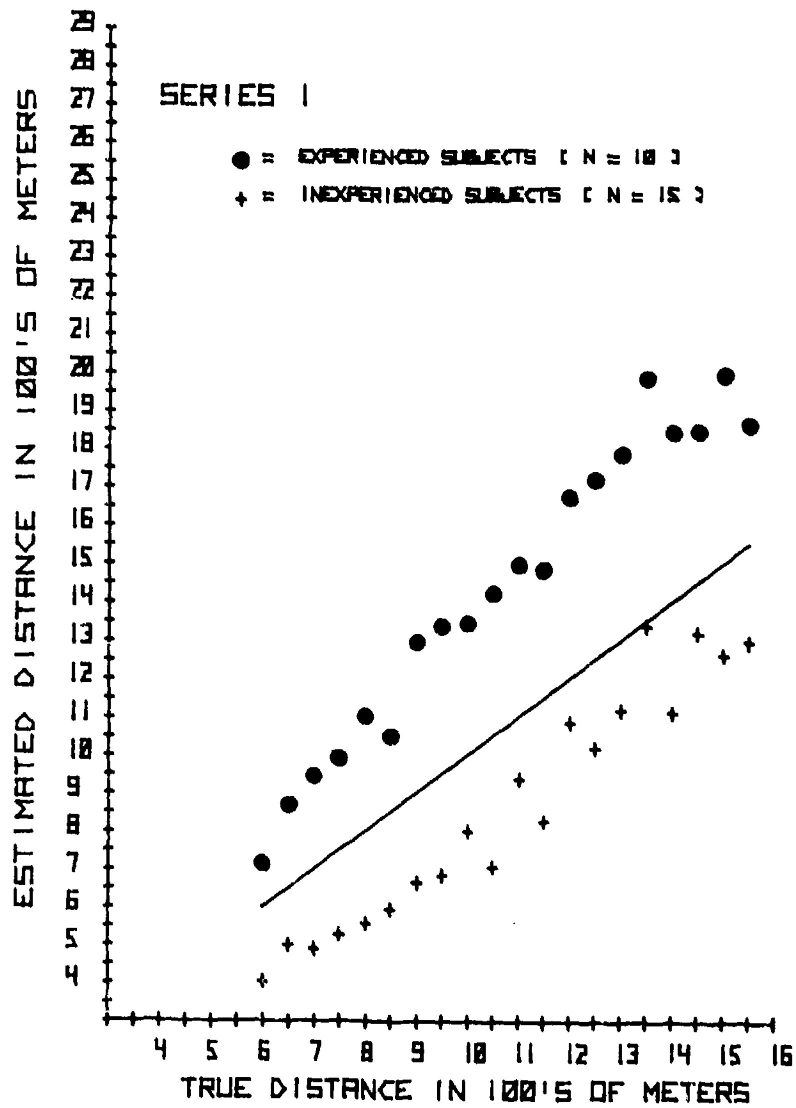

Figure 3. Group mean distance estimations for the experienced and inexperienced subjects.

As with the overall data, they show a highly consistent and nearly linear relationship to true distance. However, the two groups were substantially different from one another in their average judgments, in that the experienced group overestimated and the inexperienced group underestimated the true distances. The inexperienced group had more mean judgments within the 250-meter tolerance limit, but this would be expected since overestimaters were not bound by the limits of the viewing range.

The differences between the two groups were very consistent and occurred systematically throughout the entire target range. The causes of the differences cannot be specified at this time, although a number of factors seem to be involved, such as experience and age. In this study, these two variables are inextricably related. The experienced group was significantly older than the inexperienced group (mean age of 37.2 as compared with 22.7 years; $t=8.96$; $df=23$, $P < .0001$), with no age overlap between the groups.

Despite the systematic differences in group means, there was very high variability within each group. The variability was predominantly on the side of overestimation for experienced observers, and underestimation for inexperienced observers. These directional differences had little to do with accuracy. The experienced subjects averaged 19.2 hits out of 40 possible within the 250-meter tolerance limit; the inexperienced subjects averaged 17.8.

A comparison of the group mean distance judgments made in slide viewing with those made during field viewing showed very high correspondence across the total range of target distances, as seen in Figure 4. This is supported by the overall ANOVA, in which distance proved to be a highly significant effect. On a group basis, then, the slide data were indistinguishable from the field data, although the slide judgments tended to be overestimates and to increase as overestimates with distance.

Based on a percent error score (True Distance - Estimated Distance/True Distance), a correlation of $r = .73$ ($P < .001$) was found between the 40 field and slide trials for the 24 subjects. A nonparametric analysis ranking the 24 subjects on these scores for both field and slide conditions using a median test indicated that the subjects who tended to overestimate in the field also tended to overestimate when judging from slides, and those who underestimated in the field did likewise on the slides. The correlation of $r = .73$ indicates that over

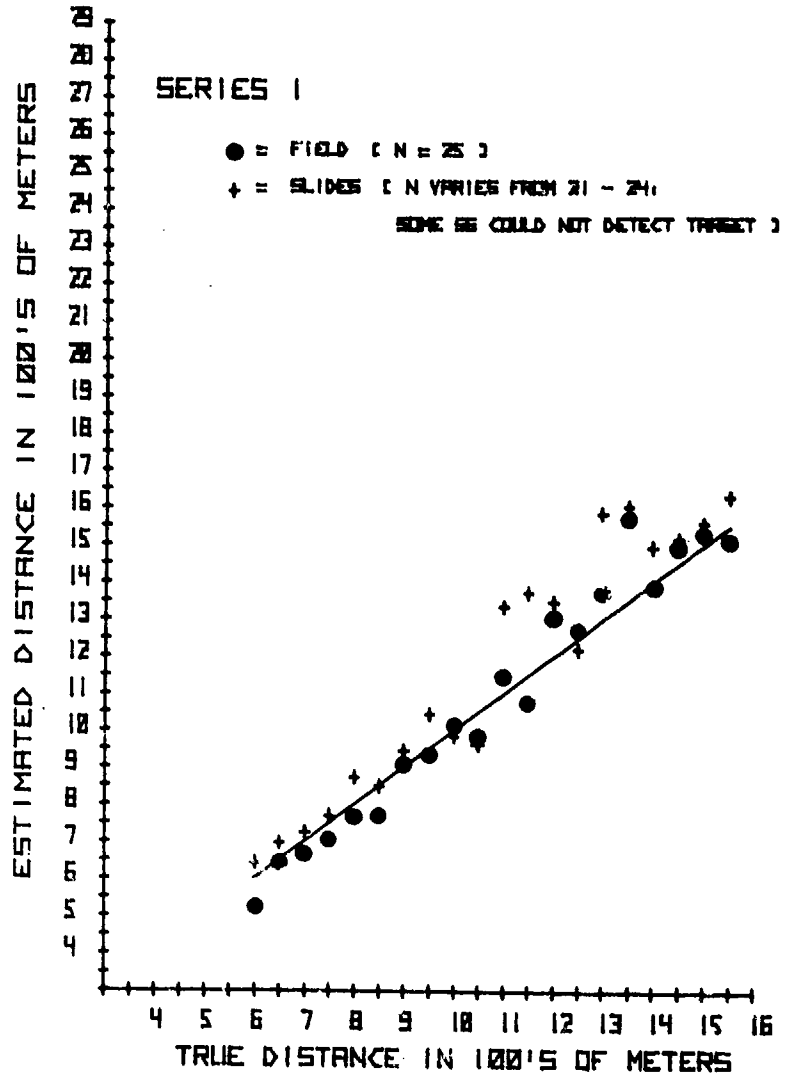

Figure 4. Group mean estimations for field and slide viewing.

50% of the variance in slide performance was accounted for by field performance, or vice versa. The median test indicates that one can predict with 80% success the over- and underestimaters in the field from their performance on the slides. It should be emphasized, however, that the over- and underestimation categories are essentially those of experienced and inexperienced observers, and may be a condition peculiar to this study alone. Certainly, generalizations should not be made solely from these data without further study.

A comparison of field and slide performance based on the average number of hits within 250 meters showed no difference between the field and slide conditions insofar as group averages are concerned. However, the misleading nature of group averages is evidenced by the fact that of the 24 subjects, 11 increased their number of hits from field to slides, 12 decreased, and one did not change. Also, these changes were not minimal. The average shift of the increasing subjects was 9.8 hits per 40 tries, and that of the decreasing subjects was 11.4 hits. Obviously, in an examination of the group data, these two substantial changes in opposite directions cancelled each other out. Thus, the group data indicate that slide viewing appears to be a quite reasonable substitute overall for actual field performance, but the individual data contradict this. The great variability and overlap between individual performances in both types of viewing indicate that the question of whether real world distance estimation can be predicted on the basis of distance estimation from slides is highly problematic and requires additional investigation. Clearly, FO performance is a highly individual matter, and must be investigated as such.

The only variable in this study which appears to have been related to the difference in performance from field to slides is that of experience (age). Using the criterion of numbers of hits within 250 meters, experienced subjects were shown to do better in the field, and inexperienced subjects proved to be better on the slides (X^2 Yates = 4.93, df=1, $P < .05$).

Presentation:

Kobrick, J. L. and B. J. Fine. Comparison of distance estimation in real scenes and projected slides, paper presented at the annual meeting of the American Psychological Association, Montreal, Canada, 3 September 1980.

LITERATURE CITED

1. Horley, D. L., W. J. Dousa and J. V. Lenoci, Human Engineering Laboratory Battalion Artillery Test (HELBAT 2 - Forward Observers). Human Engineering Laboratory Technical Memorandum 17-72), Aberdeen Proving Ground, MD, June 1972.

2. Horley, D. L., and D. J. Giordano, Human Engineering Laboratory Battalion Artillery Test (HELBAT 1). Human Engineering Laboratory Technical Memorandum 24-70, Aberdeen Proving Ground, MD, September 1970.

3. Patrick, A., et al. Weapon system training effectiveness analysis (WSTEA) -the forward observer phase 1A baseline. U.S. Army Field Artillery School, Fort Sill, OK, May 1977.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E61102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	011 Assessment of the Impact of the Environment on Military Performance
Study Title:	Assessment of Night Vision and Other Perceptual Performance During Hypoxia
Investigators:	John L. Kobrick, Ph.D., Bernard J. Fine,Ph.D., and Peter O'Mara, MAJ, MSC

Background:

The increasing importance of night operations in military planning has created a growing need for better understanding of and information about the range and limits of night vision capability. Although the basic human dark adaptation function has been well-documented (4), human night vision capability is known to be variable and inconsistent between individuals, and cannot be accurately specified for the Army population based on available group average dark adaptation functions (2). Night vision is also known to be influenced by other situational factors, such as environmental stress, particularly hypoxia (3). The present project is a collaborative effort between this Institute and Letterman Army Institute of Research to assess the effects of levels of hypoxia on night vision in the USARIEM hypobaric facility, using a newly developed computerized adaptometer developed by LAIR. Other visual indices presumed to be related to night visual capability (accommodation and night focus, vergence, linear distance judgment, luminance threshold for target detection) will also be obtained for comparison with night vision threshold performance curves.

Progress:

A research protocol for joint conduct of the study has been approved. In brief, the study will involve 18 soldier volunteers, who will be screened first for normal vision, and then will be trained intensively to perform the experimental tasks, as briefly described below.

Dark adaptation: In a darkened room, subjects will adjust recurrently flashing red and green test lights to their threshold levels of detectability over a 20-minute test period. The system is computerized to store the data and also operate a curve plotter which graphs the continuous dark adaptation threshold function.

Accommodation and night focus: Subjects will adjust the position of two luminous bars projected through a polaroid filter system to apparent equality, providing a measure of the relaxed night focus in diopters (see annual report for WU 026, Accession No. DAOG 0705, page 27).

Binocular vergence: This measure will be obtained as a complementary value to accommodative focus, in which binocular convergence under reduced illumination will be measured in diopters through a crossed polaroid filter system (5).

Linear distance estimation: Subjects will estimate the apparent distance of a military target appearing at a variety of apparent distances in a series of projected slides (see annual report for WU 011, Accession No. DAOC 6122, page 129).

Luminance threshold for target detection: Subjects will adjust the brightness threshold for detectability of a series of military targets presented as a series of projected slides. This measure will be obtained as a collateral index of the night vision thresholds to be obtained by the LAIR adaptometer.

Two-axis compensatory tracking: This measure has been shown previously to be sensitive to hypoxia exposure, and is included to obtain additional performance data under a series of hypoxia exposures, although unrelated to night vision. Subjects will attempt to maintain a random-moving cursor by compensatory manipulation of a two-axis manual joystick (1).

Following training, subjects will receive different combinations of daily exposures to hypobarically simulated altitudes of 11,000, 13,000 and 15,000 feet for periods of eight hours each, at weekly intervals. Within each period, they will be tested repeatedly on the measures described above.

LITERATURE CITED

1. Basamania, C. J. Effects of exposure to high altitude on performance of a compensatory tracking task. Master's thesis in preparation.

2. Fisher, K. E., and C. J. Carr, A study of individual variability in dark adaptation and night vision in man. Life Science Research Office, FASEB, Bethesda, MD, 1969.

3. Kobrick, J. L. and B. Appleton, Effects of extended hypoxia on visual performance and retinal vascular state. J. Appl. Physiol. 31:357-362, 1971.

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5. Wist, E. R., F. W. Hughes and R. B. Forney, Effect of low blood alcohol on stereoscopic acuity and fixation disparity. Percept. Mot. Skills, 29:83-87, 1967.

(014)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OC 6124	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61102A	3M161102BS10	CA	014
b. FORMER	6.11.02.A	3E161102BS08	00	014
c. CONTRIBUTING XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code) (U) Cell Culture Modeling of Cellular Disabilities Associated with Environmental Extremes (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS
005900 Environmental Biology; 010100 Microbiology; 002300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	1.0	81
	CURRENT 81	1.0	49

19. RESPONSIBLE DOD ORGANIZATION
NAME: USA RSCH INST OF ENV MED
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RESPONSIBLE INDIVIDUAL
NAME: PEARLMAN, ELIOT J., LTC, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME: USA RSCH INST OF ENV MED
ADDRESS: Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME: TRUSAL, Lynn R., CPT, MSC
TELEPHONE: 955-2861
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: HAMLET, Murray P., D.V.M.
NAME: DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Tissue Culture; (U)Endothelial Cells;(U) Hypothermia; (U)Frostbite; (U)Ultrastructure; (U) Platelets

23. TECHNICAL OBJECTIVE. 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Frostbite injuries to military troops result in a prolonged recovery time sometimes in excess of one year. In frostbite, endothelial cells suffer a freeze-thaw insult when an extremity freezes. Such damage often leads to hemostasis initiated by direct endothelial freeze-thaw damage and may lead to tissue necrosis. This study has developed an in vitro cell model suitable for studying cold induced endothelial cell damage and platelet-endothelial cell interaction following a freeze-thaw insult.

24. (U) An in vitro perfusion system is being used to interact platelet suspensions with both cultured endothelial cells and endothelial cells in sit on the vessel wall. Aorta segments were exposed to 37°C (control) or below freezing (-15°C or -20°C) prior to perfusion and processing for examination by both scanning and transmission electron miscroscopy.

25. (U) 79 10 - 80 09 The in vitro endothelial cell model and in vitro aorta perfusion system was used to study the interaction of bovine platelets with endothelial cells subjected to a freeze-thaw insult. Results indicate that freezing and thawing of aorta segments remove most of the endothelial cells exposing the subendothelium. Disruption of bovine endothelial cells by a freeze-thaw insult does not result in a generalized adhesion or aggregation of platelets to the endothelial cells. Platelets did adhere to the exposed subendothelium although no evidence of extensive aggregation was noted. The exact nature of this attachment is not yet known. Similarly, platelets do not attach to in vitro damaged endothelial cells but appear to adhere to the extracellular matrix produced by and underlying the cells. The reactive substance for platelet attachment in both models is believed to be collagen, but is not yet known.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	014 Cell Culture Modeling of Cellular Disabilities Associated with Environmental Extremes
Study Title:	Development of an In Vitro Endothelial Cell Model As It Applies to Cold Induced Ultrastructural Changes
Investigators:	Lynn R. Trusal, CPT, MSC, Ph.D., and Murray P. Hamlet, D.V.M.

Background:

It is known that platelet aggregation plays a major roll in hemostasis. Numerous factors are known to cause platelet adhesion and aggregation including exposure to the subendothelium. While the endothelial cell lining on the luminal surface of blood vessels is normally nonthrombogenic when intact (2,5), removal of this lining exposes the subendothelium activating platelet aggregation. Although the thrombogenicity of the subendothelium is well known; the reactivity of the endothelial cells damaged by various insults is subject to debate in the open literature. Some reports state that platelets adhere to altered or damaged endothelium (1,3) while others report the contrary (6,8). No reports have been found that investigate the response of platelets to freeze-thaw damaged endothelium such as might be encountered in a frostbite injury. This report examines such an interaction.

Progress:

Development of an In Vitro Perfusion System

It was first necessary to develop an *in vitro* system whereby platelets could be perfused through aorta segments under controlled conditions. This was accomplished by using cannulated segments of isolated bovine aorta perfused with platelet suspensions at physiological pressure. Controls were maintained at 37°C while experimentals were frozen to -15 or -20°C and thawed in a 37°C water bath. Both experimentals and controls were then perfused at 37°C, 120 mm Hg, and a flow rate of 5ml/min with platelet rich plasma (PRP) or gel filtered platelets (GFP). After 30 minutes, the vessels were drained, flushed with Tyrodes buffer and fixed with glutaraldehyde under physiological pressure for 30 min at the same flow rate. The vessels were then maintained under pressure for 12 hours at 22°C. This was followed by processing for both scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

Platelet Source and Aggregation

Two different sources of platelets were used for perfusion; platelets in PRP and platelets gel filtered to remove plasma proteins. This allowed study of the role of plasma proteins in platelet adhesion. Figure 1 illustrates GFP on a plastic substrate. Most platelets have maintained their disc shaped morphology but others have undergone shape change to include formation of pseudopodia.

Figure 1. Scanning electron micrograph of bovine gel filtered platelets. Note size of platelets in relation to red blood cell (arrow) Bar = 10 microns.

Platelets obtained from either PRP or GFP were then tested for their ability to aggregate using a platelet aggregometer and known aggregating agents which included adenosine diphosphate (ADP), collagen, thrombin and serotonin. Only after platelets were shown to be functional by their ability to aggregate were they used for perfusion. The maximum per cent aggregation response of PRP and GFP to these aggregating agents are contained in Table I. Gel filtration of platelets generally produced platelets than responded as well or better than PRP to the various aggregating agents.

TABLE I

Average Maximum Percent Platelet Aggregation*

Aggregating Agent (final concentration)	PRP	GFP
ADP (0.1 mg/ml)	60%	74%
THROMBIN (.05 units/ml)	1%	75%
SEROTONIN (1×10^{-4}M)	26%	12%
COLLAGEN (.26 mg/ml)	66%	53%

*Data represent means of 7 different experiments

Control Aortas

Figure 2 illustrates the surface morphology of a control aorta maintained at 37°C and perfused with GFP. The individual endothelial cells can be seen to protrude into the lumen of the vessel, with the blood flow in the direction of the long axis of the cells (arrow). No platelets can be seen adhering to the endothelial lining. In control vessels (37°C), where the endothelial lining was mechanically disrupted, platelets did adhere to the subendothelium (Figure 3). Occasionally a platelet was found in contact with an endothelial cell but this usually appeared to be platelet pseudopod contacting the border of the cell. Such platelets may actually be attached to filaments of the subendothelium.

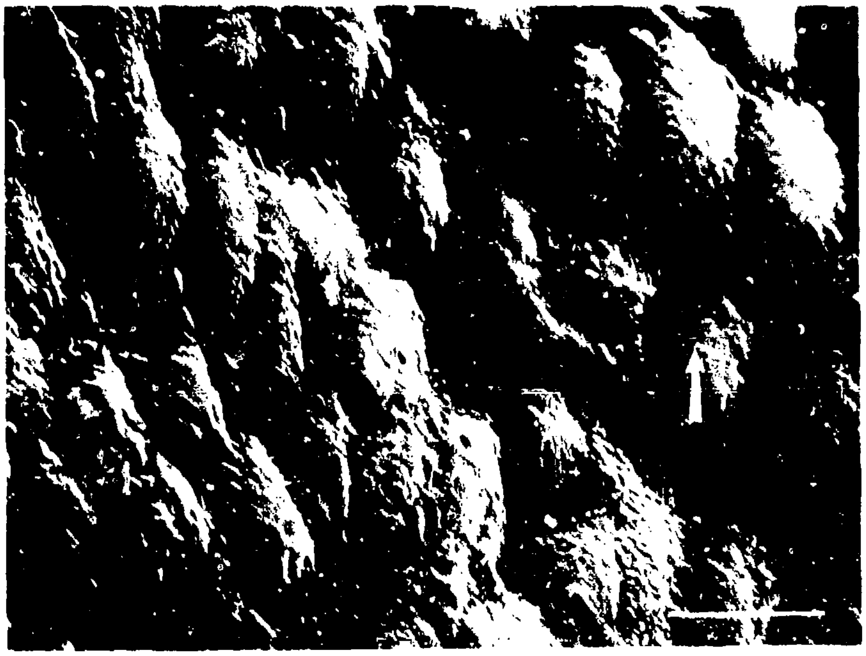

Figure 2. Scanning electron micrograph of endothelial cells on the luminal surface of an aorta maintained at 37°C (control). Bar = 10 microns.

Figure 3. Scanning eletron micrograph of gel filtered platelets attachment to exposed subendothelium of an aorta maintained at 37°C (control). Bar = 10 microns.

Experimental Aortas

The temperature and duration of freeze (-15 or -20°C) did not significantly alter the platelet interaction with the endothelial cell lining. At both temperatures and durations, the majority of endothelial cells were removed from the luminal surface with only small patches of damaged cells remaining attached to the subendothelium, or more specifically, to the internal elastic lamina (IEL).

When GFP was perfused through an aorta that had been frozen and thawed, platelets adhered to the exposed subendothelium forming a monolayer of attached platelets. Figure 4 illustrates a large area of denuded endothelium with attached platelets forming a monolayer over the subendothelium. On the right side of the figure, are damaged endothelial cells still attached to the IEL. It is easy to see that while platelets have adhered to the subendothelium they do not generally attach to disrupted endothelial cells. Occasionally, as in controls, several platelets were found in contact with endothelial cells although the extent or specific type of attachment is unknown. This may be seen in Figure 4 (arrows).

Figure 4. Scanning electron micrograph of gel filtered platelets adhering to exposed subendothelium of an aorta frozen to -15°C. Note several platelets on surface of one endothelial cell (arrows). Bar = 10 microns.

Figure 5 demonstrates an area of aorta where the majority of endothelial cells are still attached to the IEL although the cells surfaces are pitted and the cell junctions partially separated. Once again, adhering platelets seem to be largely confined to the exposed subendothelium between the cell junctions. Some platelets are seen resting on the edge of the cell although they appear also to be in contact with the subendothelium.

The relationship between attached platelets and the blood vessel wall can best be seen in Figure 6. Platelets adhering to the IEL completely surround three badly damaged endothelial cells whose surfaces contain holes and cell junctions are separated. All platelets are attached to the subendothelium including one between the junction of the two cells (arrow).

Perfusion of PRP through the blood vessels produced similar results. Once again, platelets attached to exposed subendothelium areas but did not adhere to freeze-thaw damaged endothelial cells, except in isolated instances.

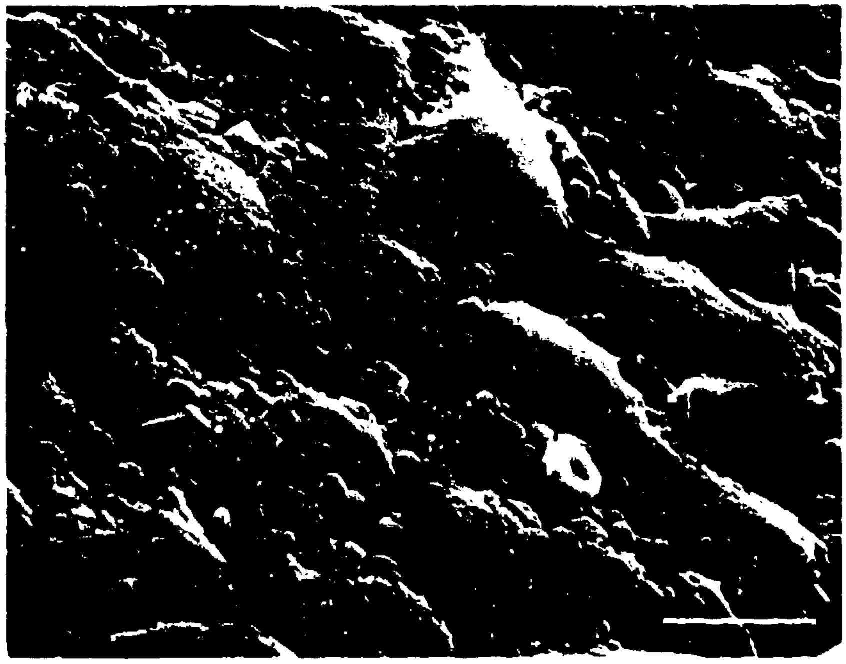

Figure 5. Scanning electron micrograph of gel filtered platelets adhering to exposed subendothelium between a patch of disrupted endothelial cells of an aorta frozen to -20°C. Bar = 10 microns.

Figure 6. Scanning electron micrograph of gel filtered platelets adhering to subendothelim of aorta frozen to $-15^{o}C$. Note disrupted surface of three endothelial cells but absence of platelet adhesion directly to these cells. Bar = 10 microns.

Conclusions

The previously discussed data support the concept that the in vitro perfusion model is a functional system for studying platelet interaction with blood vessel wall components. Platelets isolated by two different methods (PRP and GFP) respond to collagen by aggregating in an aggregometer or when exposed to collagen in the subendothelium of the vessel wall. Attachment or adhesion of platelets to the subendothelium is consistent with published data in several animal models (4,7). This subendothelium which contains all tissue layers external to the endothelium includes the internal elastic lamina, smooth muscle lamina and the external elastic lamina. Of these, the IEL immediately underlying the aortic endothelium contains both collagen and elastin. It is believed that this collagen is the primary vessel wall component responsible for platelet adhesion to the subendothelium in our in vitro model.

From the scanning electron micrographs, it can also be concluded that disruption of bovine endothelial cells by a freeze-thaw insult in vitro does not result in a generalized aggregation response by platelets in either PRP or GFP. In no instance, were platelet aggregates or large thrombi found attached to either the subendothelium or individual endothelial cells. Platelets attached to the subendothelium also showed no sign of undergoing a release reaction. Isolated examples of platelets in contact with both control and experimental endothelial cells were noted in all samples. Scanning electron micrographs do not allow evaluation of the true nature of these contacts which may represent platelet pseudopodia contact with subendothelial components rather than with endothelial cell structures. Evaluation of transmission electron micrographs, not completed at this time, should further elucidate these isolated platelet-endothelial cell interactions.

In order to further evaluate platelet interaction with endothelial cells damaged by freezing and thawing, an in vitro cell culturing model is also being used. In this system, endothelial cells are cultured in vitro on plastic substrates. Once a confluent monolayer has grown, the coverslips are placed in siliconized perfusion chambers and perfused with PRP or GFP in a similar manner to the aorta segments. Processing for SEM and TEM are then carried out. This system allows the removal of the cells from the subendothelium and reduces the number of variables that may cause platelet adhesion or aggregation. Data from this aspect of the study have not been evaluated and results will be presented in next year's annual report

Presentation:

Trusal, L. R., C. J. Baker and A. W. Guzman. Freeze-thaw induced ultrastructural damage in endothelial cells in vitro. Proc. Fed. Amer. Soc. Exp. Biol. 39:774, 1980.

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(015)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OC 6132	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	61102A	3MI61102BS10	CA	015
b. FORMER	6.11.02.A	3E161102BS08	00	015
c. XXXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code) (U) Survey Analysis of Environmental Medical Symptoms and Risk in Army Personnel (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 007900 Occupational Medicine; 012500 Personnel Selection, Training; 005900 Environmental Biology; 013400 Psychological; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 05	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	2.5	81
	CURRENT 81	5.5	77

19. RESPONSIBLE DOD ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: STOKES, James W., LTC, MC

NAME: DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Survey Analysis; (U)Symptoms Self-Reports; (U)Questionnaires/Interviews; (U)Climatic Exposure: (U)Health Risk Factors; (U)Rating Scales

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Data is needed on the number and type of Army personnel who suffer environmentally-related illness and injury; on therapies used; on troops exposed but never requiring treatment; on partially disabling symptoms which go unreported; on the nature of exposure (especially related to MOS duties); and on medical risk factors due to individual background, physical condition and health-related behaviors. Such data, obtained from Army populations, give focus to research, prophylaxis and training, and are of direct use to planners, commanders, and at-risk individuals.

24. (U) Test specific methodologies for data collection and analysis from personnel in climatic extremes and/or sustained operations during field manuevers, special training, transmeridian deployments, lab studies and in rigorous physical fitness programs. Questionnaires, interviews, record surveys and behavioral observations obtain subjective and objective data on illness and injury, as well as relevant background information. The methodology is also used in controlled laboratory experiments. Biases introduced by use of volunteer subjects are evaluated and survey sampling statistics are applied to describe subjects in terms of percentiles in Army subpopulations.

25. (U) 79 10 - 80 09 During REDCOM winter exercise Empire Glacier '80 (Ft. Drum, NY), medical cases of all types seen at the hospital, dispensaries and clearing stations were recorded, questionnaires on background, experience and training in cold were completed by a subsample, and all cases of suspected cold injury were evaluated. Exercise medical commanders were provided summaries of caseload over time for diagnostic group. Incidence of cold complaints was found closely correlated with 3-day average wind chill factor. Similar data collection planned for a summer REDCOM exercise at Ft. Polk, LA, was deferred due to TDY limitations. A follow-up study in arctic cold is planned for Exercise Brim Frost '81.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	015 Survey Analysis of Environmental Medical Symptoms and Risk in Army Personnel
Study Title:	Survey Analysis of Medical Complaints during Army Cold Weather Exercise "Empire Glaicer '80"
Investigators:	James B. Sampson, Ph.D., James W. Stokes, LTC(P), MC

Background:

The Survey Analysis project was established in FY '79 because field observations (Brave Shield XX, Empire Glacier '7 (1), etc) showed the inadequacies of available reporting on the nature and extent of medical problems during military exercises in adverse climates. Data are needed on the number and type of Army personnel who suffer environmentally-related illness and injury; on training programs and therapies used and their effectiveness; on populations at risk and troops exposed but never requiring treatment; on partially disabling symptoms which go unreported; and on the nature of exposure as related to MOS duties. Information is also needed on risk factors due to individual background, experience, attitudes, physical conditioning and health-related behaviors. Such data from Army populations can give focus to research, training and preventive doctrine, and are of direct use to operational planners, commanders and individuals at risk.

The objective of this project is to develop USARIEM's capability to collect and analyze Army data on problems of environmental epidemiology, using the techniques of survey sampling. Specific methods for data collection and analysis are developed and tested during field maneuvers or special training in extreme climates, sustained operations or long distant deployments and in rigorous physical training programs. Survey instruments include standard recording forms, questionnaires, structured interviews and behavioral observations, and systematic measurement of meteorologic conditions. An important consideration is using personnel and information channels which are already involved in the exercise to obtain necessary data, but without interfering in their regular functions.

The data from such surveys provide immediate insight into the status of troop units and preventive measures for the exercise surgeons and commanders. Published reports provide an empirical basis for planning by units tasked to deploy to similar conditions. As the data base is broadened, factor analyses may permit inferences about the relative significance of environmental parameters, training, military hazards, individual susceptibility and acclimatization to the occurrence of adverse weather injury.

Progress:

A survey of medical caseload was conducted at Fort Drum, NY over 12 days of the Readiness Command (REDCOM) cold weather Joint Training Exercise (JTX) "Empire Glacier '80." The number of personnel involved at Fort Drum are shown in Figure 1, divided among the Army Forces (ARFOR, the "friendly" brigade of ground troops), the Opposing Forces (OPFOR, the "hostile" ground brigade), the Combined Support Command (COSCOM, the support troops who serviced both sides), and the Air Force (AFFOR, those Air Force ground personnel actually in the vicinity of Fort Drum who were exposed to the same weather conditions and who were served by local medical facilities). As a result

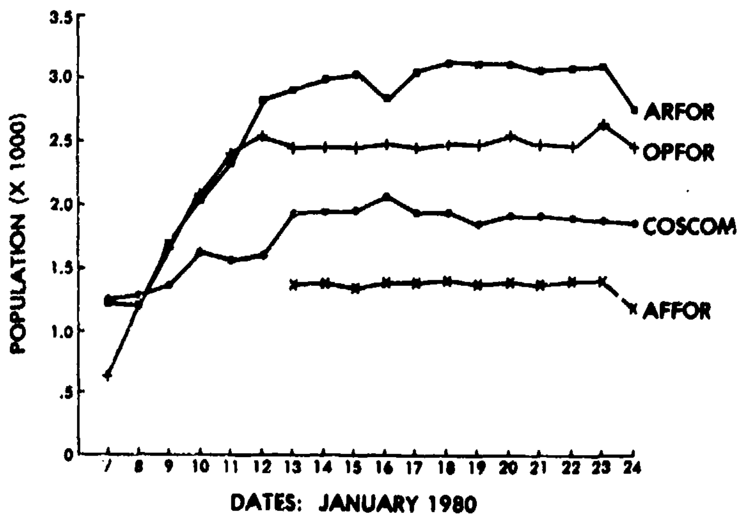

Figure 1. Daily census of the four major units during Exercise Empire Glacier '80. ARFOR = Army Forces; OPFOR = Opposing (Army Forces; COSCOM = Combined Support Command; AFFOR = Airforce (ground personnel).

of prior coordination, standard USARIEM Medical Record Log forms were utilized to record patient intake at the field hospital and clinic, the independent dispensaries used by COSCOM and AFFOR, and the combat unit dispensaries and field clearing stations of ARFOR and OPFOR. We estimate that the admitting clerks logged in over 90% of cases seen and recorded basic information, i.e. time in, time out, sex, service branch, rank, duty MOS, unit, age, duty status, complaint, diagnosis and disposition. A large subsample of cases waiting to be seen in the clinics were administered questionnaires by USARIEM personnel to determine background experience and training in cold weather. Cases of suspected cold injury were investigated further to determine circumstances of the injury, final diagnosis and disposition. Cases were catalogued on site into diagnostic categories, and summaries were provided to the REDCOM/JTX surgeon and field hospital and medical brigade commanders to supplement their own internal reports.

The daily personnel censuses (Figure 1), necessary for computation of incidence rates of medical complaints, were obtained from the JTX S-1 office. As a matter of official policy, these statistics are no longer collected with any subclassification by gender; however, at our request, this additional information was solicited from the units on three days; once before, once during and once after the 5 day field training exercise (FTX). We then estimated daily troop strengths by gender from these samples.

Daily records on weather conditions were collected from the Air Force meteorologic team at Wheeler-Sack Air Field, Fort Drum, representing averages of measurements taken at intervals throughout each 24 hours. In general, conditions were mild relative to typical weather for the area at this time of year, with much less snowfall or accumulation.

Figure 2 presents the number of cases of Adverse Weather Injury (AWI) seen each day in all of the medical treatment facilities. AWI included cases of suspected frost-bite or trenchfoot plus other miscellaneous complaints directly related to cold exposure (Table 1). Figure 2 also shows the average daily (24 hours) wind chill equivalent temperature and the average windchill over the preceding three days (72 h). Note that whereas windchill equivalent temperature on the day the AWI was reported provides only a variable correlation with number of AWI's, the prior 3-day average is more consistent. Based upon this empirical observation, a simple predictive model was established (Figure 3). The success of this model in accounting for the observed incidence of cold complaints is shown in Figure 4.

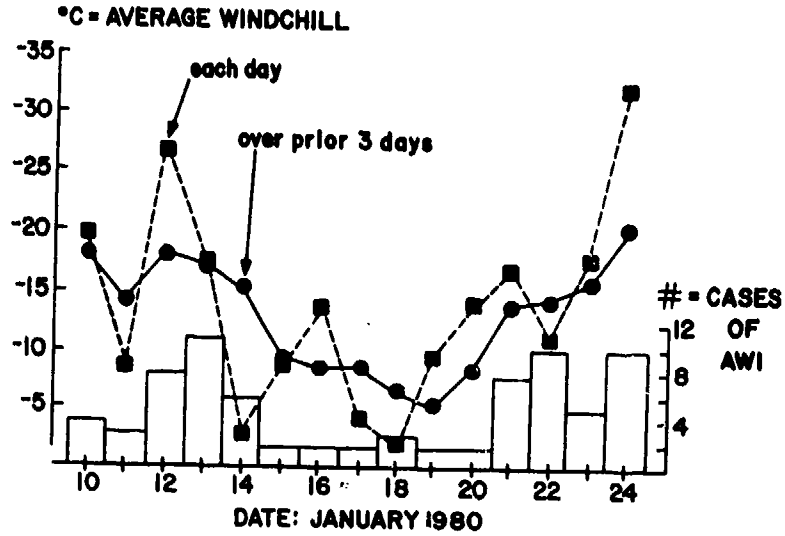

Figure 2. The average daily windchill equivalent temperature is shown for each day from 10 to 24 January (closed squares), along with the value obtained for each day by averaging the daily windchill for the three prior days (closed circles). Also shown are the number of cases of adverse weather injury (AWI) seen in the medical treatment facilities each day.

TABLE 1

Frequency of Adverse Weather Injury (AWI) Complaints (13 thru 24 Jan)

		Freq.	Ave./Day
1.	Cold Feet	18	(1.6)
2.	Frostbite (suspected)	14	(1.3)
3.	Blank/General	10	(0.9)
4.	Cold Exposure	6	(0.5)
5.	Cold Weather Evaluation	3	(0.3)
6.	Dehydration	3	(0.3)
7.	Cold Hands	2	(0.2)
8.	Numb Feet	2	(0.2)
9.	Chills	2	(0.2)
10.	Pain in Feet	2	(0.2)
11.	Swollen Feet	2	(0.2)
12.	Trench (Immersion) Foot	1	(0.1)
	TOTAL	: 65	(5.6)

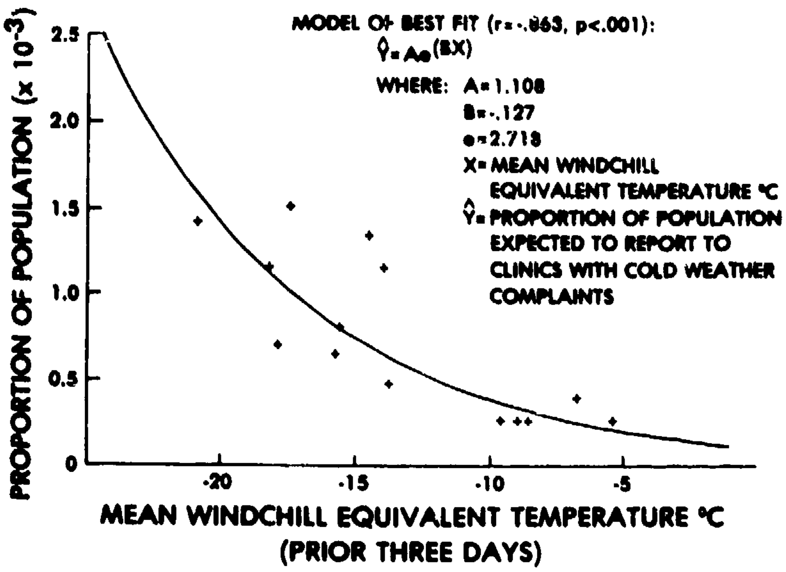

Figure 3. Model relating the observed frequency of cold weather complaints (AWI) seen in the medical clinics each day (expressed as percent of the population at risk x 10^{-3}) to the average daily windchill over the three preceding days.

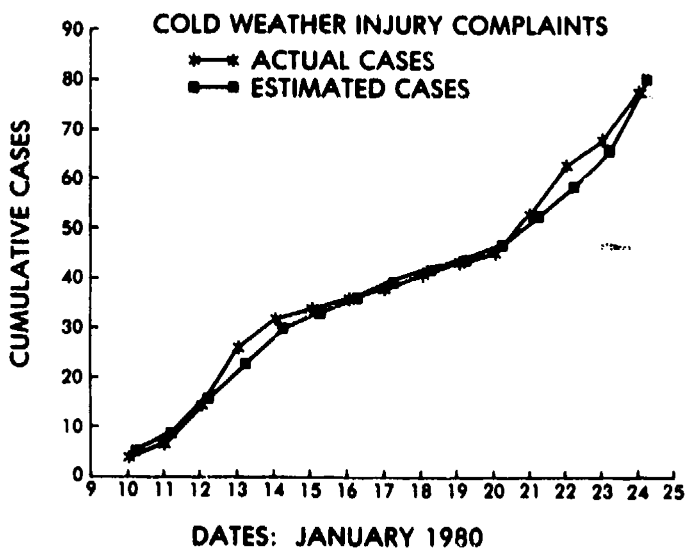

Figure 4. Comparison of the observed frequency of cold weather complaints (AWI) with the frequency predicted by the model shown in Figure 3. (The curves represent cumulative cases).

It should be noted that this model was constructed from data obtained from relatively large populations which were by no means homogenous. ARFOR and OPFOR personnel generally (but not invariably) were in the field continually while COSCOM and AFFOR were on shifts which permitted them to return to heated barracks and dining halls. Differences in exposure related to particular jobs or exposures could dramatically modify the function, so the precise equation must be used cautiously. Its value lies in its graphic demonstration of the role that <u>time</u> plays in the genesis of cold injury, -- time measured not simply in minutes or hours, but in days. The commander and preventive medicine officer who are concerned about maintaining the welfare of the troops in the cold, or the medical officer preparing his treatment facility to meet an expected caseload, should clearly be looking not only at the moment's weather but at the conditions which have been recorded over the past several days.

It should not be thought that the medical cost of cold weather training or operations can be measured only in terms of frostbite, trench-foot and specific "cold-injuries". Other illness and injury may be related to the prevailing environmental conditions, even quite directly. For example, the 1978 Empire Glacier study (1) found many orthopedic injuries to ankles and knees resulted from the troops' first experiences on skis or snowshoes (a hazard which was much reduced in 1980 due to the dearth of snow). Figure 5 shows the incidences of the cases in the different diagnostic categories for the four major units in the 1980 exercise. Figure 6 compares the incidences in the total population, divided according to gender. The relative differences in medical case presentation among the four units and the relatively higher use of treatment facilities by women are, at this point, only subjects of informed speculation which may be examined further in future studies.

The full value of this type of systematic observational research will come only from repetition of the surveys in a number of exercises which involve different units and a wide range of environmental conditions. As sample sizes in the data base increase, and as the methodology for complete, accurate data sampling is improved, it may become possible to factor out the relative influence of variables related to the weather, to duty MOS, to training programs, or to individual background and demographic data. Ultimately, Army-wide surveys conducted through MILPERCEN would then permit prediction of the likelihood of adverse weather injury in other Army units and allow planners to target preventive measures. In the meantime, the expanding data base will provide an

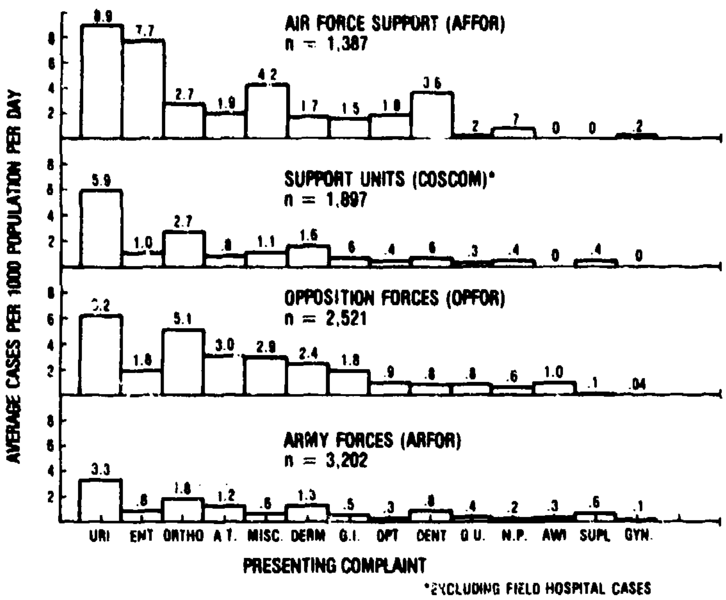

Figure 5. Average number of cases seen in medical treatment facilities per day, categorized by presenting complaint for the four major troop units. URI = upper respiratory infection; ENT = ear, nose, throat; ORTHO = orthopedic; A. T. = acute trauma; MISC = miscellaneous; DERM = dermatologic; G. I. = gastro-intestinal; OPT = eye; DENT = dental; G. U. = genito-urinary; NP = neuropsychiatric (includes headache, dizziness); AWI = adverse weather injury; SUPL = supplies (routine prescriptions); GYN = gynecologic.

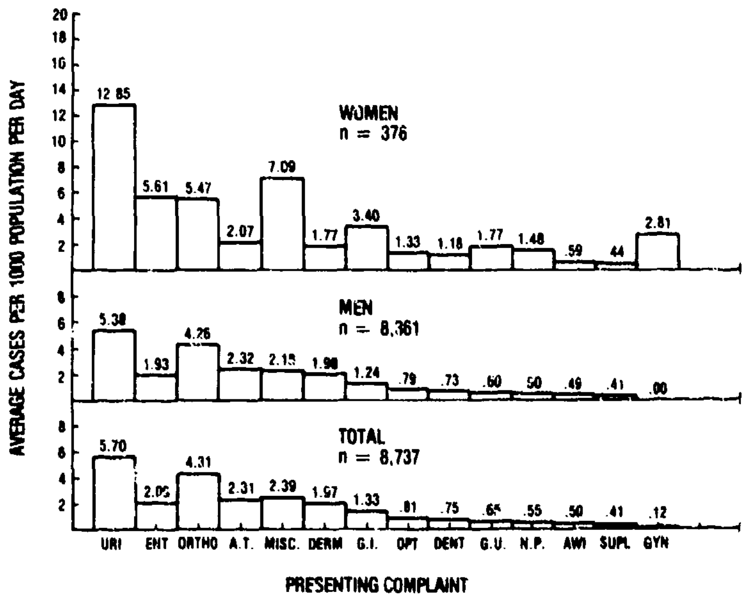

Figure 6. Average number of female and male cases seen in medical treatment facilities per day, by complaint category and expressed per 1000 women or men "at risk". The complaint category abbreviations are defined under Figure 5.

empirical basis for Rapid Deployment Force planners, unit commanders, and division or brigade surgeons who must make detailed preparations when tasked to deploy to harsh climates.

In FY '80, a survey similar to that at Fort Drum was planned for REDCOM JTX "Brave Shield" in August at Fort Polk, LA. We were especially interested in a New York National Guard armored battalion which would presumably have achieved less heat acclimatization than other battalions permanently stationed at Fort Polk. However, this study was cancelled due to TDY funding limits. Another cold weather study is planned in conjunction with REDCOMs JTX "Brim Frost" (January 1981, in Alaska) to extend the data base to include sub-zero arctic winter conditions. If resources permit, hot weather conditions will be addressed in a REDCOM JTX in August.

Publication:

Sampson, J. B., J. W. Stokes, J. G. Barr, J. B. Jobe and M. P. Hamlet. Morbidity rates during a military cold weather exercise: Empire Glacier 1980. USARIEM Technical Report, in preparation.

LITERATURE CITED

1. McCarroll, J. E., R. E. Jackson, C. A. Traver, R. C. Langevin, P. W. Phair, C. A. Murray and L. J. Farese. Morbidity associated with cold Weather training. Milit. Med. 144, 680-684, 1979.

2. Hawryluk, O. Why Johnny can't march: cold injuries and other ills on peacetime maneuvers. Milit. Med. 143, 377-379, 1977.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6131	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A879	BB	121
b. FORMER	6.27.77.A	3E162777A845	00	041
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)*

(U) Prophylaxis Susceptibility and Predisposing Factors of Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

002300 Biochemistry; 002600 Biology; 003500 Clinical Medicine; 005900 Environmental Biology; 012600 Pharmacology; 012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
10 01	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	5.0	171
	CURRENT 81	3.0	120

19. RESPONSIBLE DOD ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER

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NAME: KELLY, John, D.V.M., MAJ, VC DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U)Peripheral Blood Flow; (U)CIVD; (U)Thermography; (U)VO_2 max; (U)Hypovolemia

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Total allied casualties due to cold injury in WWI, II and Korea exceeds one million cases. Numerous predisposing factors such as dehydration, shock, level of fitness and fatigue will be studied for their impact on susceptibility. Evidence suggests that racial background, cold experience, smoking habits and home of origin may be important to increased cold sensitivity. Peripheral rewarming response will be studied utilizing infrared thermography and multipoint thermocouples. The impact of physiologic, environmental and anthropometric factors in cold injury susceptibility will be studied.

24. (U) Multipoint thermocouples and infrared thermography will be used to define the onset of vasoconstriction and vasodilation in normal and clinically identified abnormal individuals. Reconditioning of the shut down response will be tried. The neural control of cold induced vasodilation (CIVD) will be studied by interrupting peripheral autonomic pathways and altering the baroreceptor set point. Fluid and electrolyte balance during hypothermia will be studied in an animal model. The degree of dehydration of soldiers operating in cold will be studied.

25. (U) 79 10 - 80 09 Software development for analysis of thermograms is complete and being applied to 36 cold injured rabbits (+10 to -20°C). CIVD is being characterized by an animal model studying seven physiological parameters. Classical conditioning of the rewarming response in cold sensitive individuals is under way. Protocols to study dehydration in both man and animal have been prepared and approved. A protocol to study peripheral cooling after exercise has been submitted for publication.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS, AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	041 Prophylaxis, Susceptibility and Predisposing Factors of Cold Injury
Study Title:	Induced Peripheral Vasodilation in Cold by Classical Conditioning
Investigators:	Jared B. Jobe, CPT, Ph.D., James B. Sampson, Ph.D., Donald E. Roberts, Ph.D. and William P. Beetham, Jr., M.D. (Lahey Clinic Foundation)

Background:

Cold-induced vasodilation (CIVD) enhances one's resistance to frostbite and other cold injuries (Wilson & Goldman, 1970). Evidence from a number of studies suggests that older individuals, women, blacks, thin persons, heavy smokers, and previously cold-injured individuals are all likely to be more susceptible to frostbite (Yoshimura & Iida, 1952).

Most instances of cold sensitivity appear to be of neurophysiological origin (Krupp & Chatton, 1973); thus alterations in nervous-system response to external stimulation such as cold should alter cold-sensitive symptomatology.

The most severe form of cold sensitivity is Raynaud's disease, an extreme spasm of the blood vessels of the hands and/or feet accompanied by color change. Traditional treatment has consisted of drugs, avoidance of cold and emotional upset or in extreme cases, sympathectomy. However, recent research has shown that there are behavioral methods of inducing vasodilation.

The most widely known method of behaviorally increasing blood flow to the hands is biofeedback, involving operant conditioning (e.g., Roberts, Kewman, & MacDonald, 1973). Relaxation has also been used to increase peripheral blood flow (e.g., Surwit, Pilon, & Fenton, 1978). Attempts to apply these procedures to Raynaud's patients have been moderately successful.

In a recent study, Marshall & Gregory (1974) classically conditioned eight cold-hypersensitive volunteers, three of whom exhibited primary Raynaud's disease, to vasodilate in cold. Each was given several whole-body exposures to cold air (0^oC) while simultaneously having their hands in a warm (42^oC) water bath. The results showed significant differences between pre- and post-treatment tests for both normal and cold conditions.

The majority of these behavioral studies did not employ control groups, and many reported small or subjective measures of improvement. Additionally, the results are equivocal in that some methods of treatment have not been effective when employed alone or used in conjuction with other methods. In still other studies, the procedure(s) responsible for improvement cannot be isolated because various methods are used together. Experimental evidence is needed to confirm Marshall and Gregory's results using control trials and then to determine which method of behavioral treatments (classical conditioning, biofeedback plus relaxation, relaxation alone) is most effective.

Potential military applications include prophylactic treatment of cold-hypersensitive individuals and of those who have been made hypersensitive by previous cold injury.

Progress:

A protocol to study classical conditioning of hand vasodilation on exposure to cold, using subjects with severe cold hypersensitivity, was appoved by the Human Use Review Committee (USARIEM), the Human Subjects Research Review Board (OTSG), and the Lahey Clinic Human Research Committee.

William P. Beetham, Jr., M.D. of the Lahey Clinic Foundation (LCF) agreed to participate as an investigator. Dr. Beetham is a rheumatologist and former MC officer, and has had considerable experience with Raynaud's patients. The records of over 200 patients recently seen at LCF were reviewed to select idiopathic Raynaud's patients from the local area to recruit as subjects. After approval of their primary physicians, letters were sent to patients to recruit the necessary sixteen Raynaud's subjects.

Each volunteer who is accepted will be given a blood test to rule out concurrent disease (e.g., rheumatoid arthritis), and will complete several questionnaires to assess variables related to conditionability (introversion-extraversion; anxiety). Subjects will be given a ten-minute preliminary test trial to determine their pre-treatment response (digital temperature drop) to cold temperature (0^oC), followed by 27 ten-minute treatments over three weeks. Treatments will consist of simultaneous exposure to cold air (0^oC) and placement of the hands in a hot water bath (42^{o}C). The series of treatments will be followed by a ten-minute post-test of response to cold (0^{o}C). Controls will receive the same procedure without the hot water bath (Group 1) or without either the hot water bath or exposure in the cold (Group 2).

A computer program to record and analyze the data was developed with assistance from Information Sciences Branch. Equipment test trials were run in the cold chamber using normal subjects, followed by pilot trials using two cold hypersensitive and two Raynaud's subjects. Twelve conditioning trials were run during August, three per day for four days over a two week period. All four subjects demonstrated improved blood flow for the hands on the test trial, although the magnitude of the results was not as impressive as that demonstrated by Marshall and Gregory (1974). It is hypothesized that additional trials and colder ambient temperatures are necessary to demonstrate conditioning of a greater magnitude. Accordingly, three treatments per day for nine days over a three week period will be given.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	041 Prophylaxis Susceptibility and Predisposing Factors of Cold Injury
Study Title:	Physiologic Changes During Exercise in the Cold
Investigators:	J. Grant Barr, CPT, MSC, Ph.D. and Donald E. Roberts, Ph.D.

Background:

Recent data from this laboratory suggest that dehydration has a pronounced effect on peripheral cooling rate (1). Dehydration could thus predispose the soldier to cold injury and would decrease performance in the cold. How common dehydration is in the soldier operating in cold climates is not clear.

Diminished water intake might be expected due to the decreased availability of water in cold climates. The arctic is a polar desert with annual precipitation over a large portion between only one to six centimeters (2). Even where frozen water is available as ice and snow, the time and energy requirements to melt adequate amounts are not available to the soldier. Additionally, thirst mechanisms appear to be inadequate to completely replenish fluid losses (3).

Water loss is increased by diuresis in the cold (4). Water would also be lost as sweat during exercise in the cold, especially when cold weather clothing is not properly ventilated to allow heat to escape. In addition, the low humidity in cold regions increases insensible water losses via the respiratory tract. Fluid losses are enhanced by additional weight and bulk of cold weather clothing and equipment.

Although data exist describing the water metabolism and physiology of man in the cold, these data are misleading and not directly applicable to the field soldier. One laboratory study reported no change in blood volume and extracellular fluid volume in men exposed to cold for 5 hours a day (5), whereas other studies showed a decline in blood volume with hemoconcentration (6) and a decline in extracellular fluid volume (7).

In field operations, the data are equally equivocal. One study showed only an initial hemoconcentration and negative water balance in soldiers bivouacked in cold climates (8). After 24 hours, values returned to normal. Likewise, no changes in plasma volume were seen in four subjects bivouacked for 3-1/2 weeks (9). This failure to detect changes may be due to the sample size as plasma volume declined from 5.0 to 4.8% in this study. Nevertheless, one study showed an 8% weight loss (5% attributable to water loss) in men bivouacked with water _ad libitum_ but no food (10).

In summary, the lack of substantiated data and the likelihood that dehydration may occur in the field soldier warrant further physiological investigation of the soldier in the field.

The object of this investigation is to determine whether soldiers operating in cold climates dehydrate as evidenced by indirect measures (urine and blood chemistry profiles). This project constitutes the field portion of a study designed to evaluate the alterations in fluid and electrolyte balance that occur in soldiers exposed to field conditions.

A field training exercise (Brim Frost) engaging several thousand soldiers will be conducted in Alaska during January and February 1981. A number of measurements will be obtained prior to, during, and immediately after exposure to field conditions. Approximately 50 volunteer subjects (one platoon) will be studied. These will be either regular US Army or US Marine Corps soldiers. Samples will be taken at the duty station of the individuals before, during and after field operations. Subjects will sleep in conventional military tents and will be provided standard military rations while in the field. Urine and blood samples will be collected to determine fluid and electrolyte balance of the subjects. The blood volume will be measured by a clinical dye dilution method in a subset of ten individuals. A related investigation is planned to investigate in more detail the changes observed in the present study.

Progress:

Protocol has been accepted by Human Use Review Committee. Necessary equipment and supplies are on hand or have been ordered. Coordination for the logistical needs of the study is underway. The investigation will be conducted during BRIM FROST Joint Training Exercise, Ft. Wainwright, Alaska in January-February 1981.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	041 Prophylaxis Susceptibility and Predisposing Factors of Cold Injury
Study Title:	Neural Influences in Cold-Induced Vasodilation
Investigator:	Carl A. Ohata, CPT, MSC, Ph.D.

Background:

There are several physiological responses to cold exposure which appear to be controlled by the nervous system. During immersion of a hand in ice water, there is an immediate peripheral vasoconstriction, cold pressor response and cold pain. A cold-induced vasodilation (CIVD) occurs after several minutes of immersion and is thought to function as a protective measure against cold injury in the extremity. Although previous studies dealt with each response independently, it is probably of greater significance to view them collectively as a complex sequential physiological response to the common stimulus of immersing a limb in cold water.

The neural influences affecting CIVD remain unclear. It is the purpose of this study to thoroughly examine the role of the autonomic nervous system in regulating CIVD. The specific neural pathway influencing CIVD will be identified by selective sympathectomy (bilateral resection of the lumbar and lower thoracic sympathetic chain) and parasympathectomy (bilateral vagotomy). The role of baroreceptors in initiating a reflex peripheral vasodilation (i.e. CIVD) will also be studied. A thorough understanding of the regulation of CIVD may contribute significantly to prophylactic measures against frostbite and other cold related injuries.

CIVD was originally monitored using only surface temperature as an index of peripheral vasomotor function. Only a few studies have actually attempted to monitor the change in peripheral blood flow for which this response was termed. Consequently the purpose of the initial phase of this study was to determine if there is a better index of CIVD by monitoring several cardiovascular (femoral arterial blood flow, mean blood pressure, ECG, heart rate) and thermoregulatory (skin temperature, heat flow, rectal temperature, ambient temperature) parameters.

Progress:

The cat, which had previously been shown to exhibit CIVD responses in its footpad, was selected as the animal model. Each cat was pre-anesthetized with ketamine and anesthetized with chloralose (50 mg/kg i.v.). An endotracheal tube was inserted below the level of the larynx and the cat was artificially ventilated with a positive-pressure respirator to maintain end-expiratory CO_2 at 4-5%. A femoral vein was cannulated for infusion of anesthetic and for fluid replacement with lactated Ringer's solution. The ipsilateral femoral artery was cannulated for monitoring blood pressure with a strain gauge transducer. The contralateral femoral artery was isolated and an electromagnetic flow probe was attached for monitoring of hindlimb blood flow. Surface temperature and heat flux were monitored with probes taped to the footpad. Rectal temperature was maintained within normal limits with a heating pad. Ambient temperature was also monitored. ECG was monitored with standard limb leads and heart rate was derived from the QRS spike with a biotachometer. All parameters monitored were calibrated before each experiment. The hindlimb was inserted into a glove to keep it dry and cooled by immersion in a -3^{o} to -10^{o} C bath. The chronological sequence of each experiment involved collection of control data for 0.5 hour, a 2 hour immersion period, a 0.5 hour control period, and another 2 hour immersion period. Physiological data was recorded in the following manner: monitoring devices attached to the cat were conditioned by amplifiers and recorded on chart recorders, the same signals were recorded on magnetic tape, the signal leaving the tape recorder was sent on-line to a computer for storage, computation and re-plotting. These measurements were necessary to understand the relationship between cardiovascular and thermoregulatory responses, and the sequence of these responses.

Initial experiments are in progress to determine which parameters serve as good indices of the CIVD response. Preliminary findings indicate that mean blood flow in the femoral artery, surface temperature of the footpad and heat flow from the footpad are all satisfactory indices of the CIVD response. When evaluated in terms of magnitude of the CIVD response, heat flow is the best index followed by blood flow then skin temperature. When comparing the sequence between these three parameters, blood flow generally precedes approximately simultaneous changes in skin temperature and heat flow. Further analysis of the data will include: the duration until the first CIVD, the minimum value before the first CIVD, the maximum value during the first CIVD, the amplitude of the first CIVD, similar values for all subsequent CIVD responses, and the frequency of CIVD responses during each immersion period.

The data for simultaneously recorded cardiovascular parameters suggests that there exists a relationship between changes in blood pressure and the CIVD response. This is evidence that a cold pressor response may be necessary to initiate, presumably via the baroreceptor reflex, peripheral vasodilation and warming of the extremities. During the continuous cold stress simulus, mean blood pressure is oftentimes labile. Heart rate also is changed (tachycardia or bradycardia) but is difficult to relate to the other parameters since it is less labile.

The preliminary data confirms the involvement of the autonomic nervous system in regulating the CIVD response. More data must be collected on the characteristics of the CIVD response since there exists substantial variation in the response among different individuals, among the two immersion periods, and even within the same immersion period.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	041 Prophylaxia Susceptibility and Predisposing Factors of Cold Injury
Study Title:	Thermographic Evaluation of Experimentally Produced Cold Injury of Rabbit Feet
Investigators:	John A. Kelly, MAJ, VC, D.V.M. and Murray P. Hamlet, D.V.M.

Background:

Previous research conducted on the thermographic evaluation of experimentally produced frostbite utilized the production of a fourth degree necrotizing lesion (1). In that study, the patterns of skin temperatures, as measured by thermography, enabled the prediction of a line of demarcation and extent of subsequent sloughing early in the course of frostbite injury. After four hours, the thermographs of the individual rabbit paws, showed marked temperature gradients and by 24 hours the thermographic patterns were well defined and clearly depicted the tissue that would slough. Although the main arterial blood supply was still demarcated, there were parallel isotherms running from the lateral border to the medial border at the freeze line. In that study points on the bottom of each foot were chosen for statistical analysis of temperature differences at each time postthaw. The points were chosen to reflect the areas of major blood supply proximal and distal to the freeze line. The use of these points to represent the entire area of the extremity is limiting, therefore, a technique for measuring the total surface area at any one temperature was developed using the video disk memory and a thermovision software system. The purpose of this research is to determine the value of thermography as a prognostic tool in differentiating degrees and extent of tissue damage using the technique for measuring total surface area developed by Information Sciences Branch.

Progress:

Progress on this protocol was, again, hampered by mechanical and electrical problems with the equipment up until the end of April 1980. Since May, however, the equipment has worked well except for some problems with the video disk memory and a total of thirty-six rabbits have been induced with cold injury and the data from these rabbits has been digitized and stored in the computer. The temperatures used for the induction of cold injury were between +10°C and -20°C.

A technique for hard copy plotting of time/temperature curves using a Tektronix plotter of the information obtained from the Numatron has been developed by the Information Sciences Division and has been applied to each of the cold induced rabbits (2). This program plots time/temperature curves for rectal, foot, cold bath and hot bath temperatures.

The thermovision software system has been implemented to include the following: (1) the use of the Tektronix system for hard copy computer print outs of object percentages of temperature ranges and actual foot outlines of computer stored thermographs. (2) splitting of computer stored thermographic pictures into four areas instead of two. (3) mean temperature of each of the four areas of the split picture. (4) area of each of the four areas of the split picture. Utilizing these new programs it is now possible to determine the mean object temperature and the object area of all or part of each foot on each of the digitized and computer stored thermographs. Analysis and correlation of this data is underway at this time.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA CB 6144	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☑ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	~~62777A~~	~~3E162777A879~~	~~BA~~	~~122~~
b. ~~CONTRIBUTING~~ FORMER	~~6.27.77.A~~	~~3E162777A845~~	~~00~~	~~042~~
c. ~~CONTRIBUTING~~ XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)*

(U) Models of Heat Disabilities: Treatment and Diagnosis (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

005900 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	6.0	273
	CURRENT 81	6.0	181

19. RESPONSIBLE DOD ORGANIZATION

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RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* MAGER, Milton, Ph.D.

TELEPHONE: 955-2871

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HUBBARD, Roger, Ph.D.

NAME: FRANCESCONI, Ralph P., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Disabilities; (U)Military Heat Stress; (U)Pathology Model; (U)Physiology; (U)Biochemistry; (U)Behavior; (U)Tolerance; (U)Heat

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The use of model systems to develop new or modified forms of treatments or diagnosis for the various disabilities, injuries and performance decrements associated with military operations in the heat.

24. (U) A variety of agents will be evaluated for their efficacy in reducing core temperature, decreasing the pathological effects of hyperthermia, increasing performance, or alleviating the symptomatology of heat illness among humans or animals acutely exposed to high environmental temperatures or work regimens. Additionally, a variety of clinical and physiological parameters will be evaluated for their usefulness in the early diagnosis of heat illnesses, and to characterize in animals and humans those who have experienced or are susceptible to heat related injury.

25. (U) 79 10 - 80 09 Rats made potassium (K^+) deficient through dietary restriction demonstrated a dramatic predisposition to exercise-induced hyperthermia. The rate of core temperature increase per kgM of work done was more than double that of controls (0.12 vs 0.05 °C) despite remarkable reductions in exercise performance (26 vs 53 kgM or work done). Heart lesions (90% incidence) but not kidney lesions were induced by low K^+ feeding. K^+ depletion could result in an increased rate of heat illness. In another study, we found hematocrits and other blood parameters are different if the blood is drawn from a peripheral (tail vein) than a central (jugular or aortic) site. Further, the central and peripheral hematocrits do not change similarly in response to shifts in body fluids.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	042 Models of Heat Disabilities: Treatment and Diagnosis
Study Title:	Effect of Low Potassium Diet on Rat Exercise Hyperthermia and Heatstroke Mortality
Investigators:	Roger W. Hubbard, Ph.D., Milton Mager, Ph.D., Wilbert D. Bowers, Ph.D., Irwin Leav, Ph.D. and Gerald Angoff, M.D

Background:

In assessing the possible role of some predisposing condition in the etiology of heatstroke, it could be helpful to ask whether this factor would: 1) alter the onset, intensity or duration of hyperthermia or 2) increase or decrease the body's tolerance to a given heat load. It is now well-established that the potential exists for developing moderate to severe potassium deficits via increased losses through sweat glands and urine during training and acclimatization (17,18), and several authors have postulated that potassium depletion may play an important role in the pathogenesis of heat exhaustion, heatstroke and complications brought about by these conditions (4, 9, 19, 21). Although the characteristic muscular weakness often associated with potassium depletion (32) would not appear to make exertional hyperpyrexia more likely, certainly the polyuria could augment water deficits and the impairment of sweating could contribute to both more intense and prolonged hyperthermia. Another consequence of potassium deficiency is an impairment in muscle of exercise hyperemia (20) and the storage and synthesis of glycogen (17). It is not known whether the metabolic defect in glycogen metabolism would result in more rapid exertion-induced hyperthermia but certainly the documented reduction in blood flow through working muscle would not facilitate the transfer of heated blood to the skin.

Shibolet et al. (28), however, have questioned the role of potassium depletion in the etiology of heatstroke and this skepticism rests on the assumption that potassium levels could reflect not only the duration of the prior training but also the duration and severity of the heat injury itself (1, 3, 5, 6, 18, 25, 31) The paradoxical finding, however, that modest hypokalemia coexists with severe lactic acidosis has been cited by Knochel (8) as support for a pre-existing potassium deficiency.

It is not known whether total body potassium deficiency would reduce the risk of myocardial potassium intoxication in the later stages of severe heatstroke but certainly other consequences of potassium deficiency could reduce the tolerance to heatstroke hyperthermia (2, 17, 22, 25, 27). Despite this, there is no clear evidence that potassium deficiency predisposes to either exertion-induced hyperthermia or increases the rate of heatstroke mortality. This provides the basis for this study on the effect of low potassium diet on rat exercise hyperthermia and heatstroke mortality.

Progress:

The male Sprague-Dawley rats (Charles River CD strain) weighed between 250-300 g and were fed either a control or "low potassium" (Low K^+) diet (8 mEq potassium per kg) complete with vitamins (ICN Nutritional biochemicals) for 32 days. As noted by the manufacturer, this diet is also low in magnesium (400 mg magnesium per kg) and, therefore, was supplemented with 1 g each of magnesium carbonate and magnesium chloride per kg (26). The control animals were fed the same diet, including the magnesium supplement, to which had been added 5.0 g each of K_2HPO_4 (Sorenson's salt) and KCl per kg. Thus, the low potassium and control diets contained 8 and 125 mEq potassium per kg diet, respectively. A total of 182 rats were assigned to either a control (n=60) or low-potassium (Low K^+, n=122) group. Following the 32 days of experimental feeding, 36 control (24 at 24 hours, post-fast; 12 at 48 hours, post-fast) and 50 Low K^+ fed rats (24 at 24 hours, post-fast; 26 at 48 hours, post-fast) were sacrificed under methoxyflurane anesthesia for blood and tissue analysis. The remaining animals were fasted 24 hours and then run to exhaustion on a motor-driven treadmill at either 15° C (12 controls and 36 potassium-depleted) or 20° C (12 controls and 36 potassium-depleted). Rats ran up a 6° incline at 11 m/minute and were allowed a 2-minute rest after 20 and 40 minutes of work. Exhaustion was achieved under a shock-avoidance contingency; it was defined as that point at which rats could not keep pace and when placed on their backs would not right themselves. After reaching exhaustion on the treadmill, rats were monitored at 26° C ambient while resting in plastic cages lined with wood shavings. After recovery (t core <40.0° C) animals were returned to metabolic cages (26° C) and allowed water but no food for 24 hours. All rats alive after 24 hours were counted as survivors.

Run rats were sacrificed after 24 h or agonally (terminal convulsions or apnea). If the animals died overnight, however, blood and tissue samples were lost. Blood was obtained via cardiac puncture under methoxyflurane anesthesia. Immediately after the rats were exsanguinated, the following tissues were removed for histological examination: heart, kidney, liver and gastrocnemius muscle. During fasting periods, consecutive 24 hours urine samples were collected under toluene in metabolic cages and the following determinations were made: volume, osmolality, potassium, total protein and occult blood (0 to 3+, Bili-Labstix, Ames). Significance testing was carried out by using the student t-test. P values >0.05 are omitted from the tables. Work done was calculated from the formula:

kg•m = body wt (kg) x running time (min) x treadmill speed (m/min) x inclination of treadmill (sin)

Rats fed the Low K^+ diet gained weight at only one third the rate of controls (Table 1) and as a result, weighed approximately 106 g less than the controls (-25%) prior to exercise. Although there was a tendency within each group for the animals run at 15° C to run longer than those at 20° C, the differences were not statistically significant; therefore, the performance data obtained at both ambient temperatures were combined and is tabulated in Table 2. There were more fatalities among those animals exhausted at 20° C than at 15° C (2 of 3 controls, 12 of 15 Low K^+). In both control and Low K^+ groups, fatalities had run longer and had done more work (kg M). More striking, however, were the reduced run times for the rats consuming the Low K^+ diet. As

Table 1

Effect of the Low Potassium Diet on the Weight Gain of the Rat

Group	n	Days on Diet	Wt. Gain Per Day (g)	Wt. Pre Fast (g)	Wt. Post 24 h Fast (g)
Control Diet	60	32	5.2 ± 1.0	443 ± 33	419 ± 32
Low K^+ Diet	122	32	1.7* ± 0.6	329* ± 32	313* ± 31

*Low K^+ values (mean ± S.D.) significantly different from controls ($p < .05$)

Table 2

Effect of Low Potassium Diet on Rat Treadmill Performance

	Body Wt. Loss (%)		Run Time (min)		Work Done (kg M)	
Group	Control	Low K^+	Control	Low K^+	Control	Low K^+
Post-Run Survivors (24 h)	2.4 ± 1.4	2.0 ± 0.8	109 ± 42	69* ± 38	53 ± 20	26* ± 14
(n)	(21)	(57)	(21)	(57)	(21)	(57)
Post-Run Fatalitites	3.2	2.4 ± 0.9	161† ± 56	92*† ± 38	78† ± 29	33*† ± 14
(n)	(1)	(10)	(3)	(15)	(3)	(15)

*Low K^+ values (mean ± S.D.) significantly different from controls ($p < .05$).

†Fatalities values significantly different from survivors ($p < .05$).

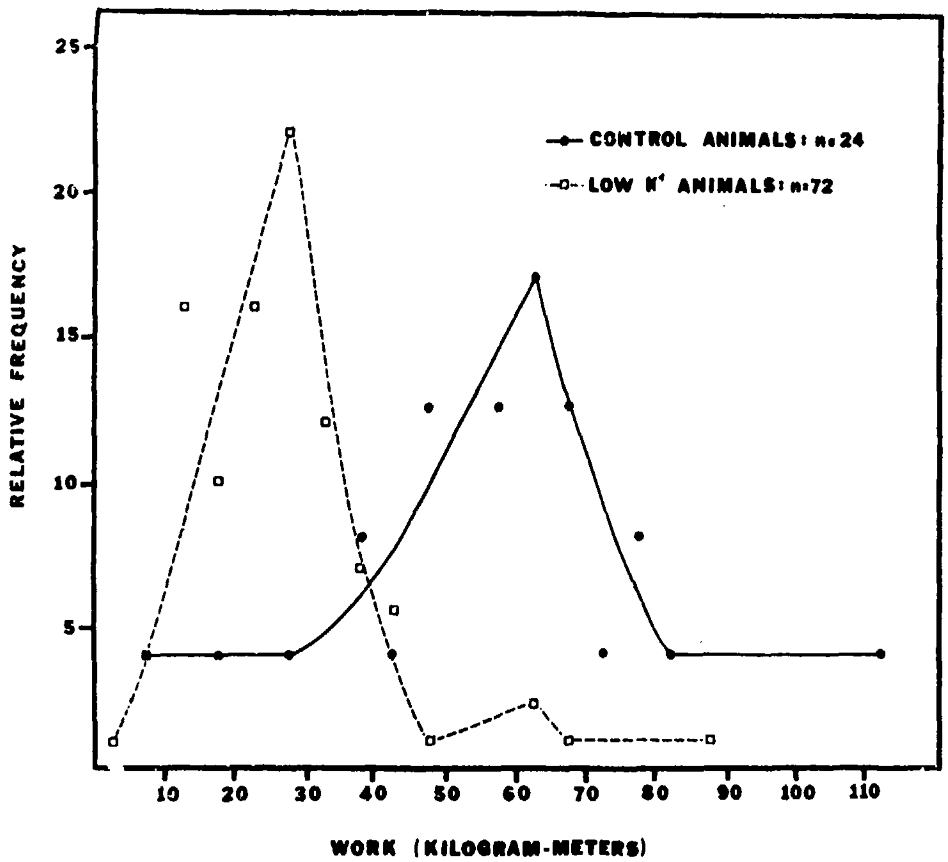

Figure 1. Frequency distribution curves of treadmill (6° incline, 11 m/min) work done prior to exhaustion by untrained rats. Prior to this exhaustive exercise, the rats had been fed either a control or low potassium diet (Low K^+) for 32 days.

a result, these lighter rats, accomplished less than one-half of the work done by the heavier control anim... illustrated in Figure 1, the distribution frequency of work done by each group before exhaustion appears normally distributed. Moreover, these curves serve to highlight the marked differences in the treadmill performance of each population.

There were no significant differences between the resting, pre-run core temperatures (Tc) of control and Low K^+ groups (Table 3). Likewise, there were no differences in Tc between potential survivors and fatalities (pre-run). On the other hand, as has been reported previously (15) the post-run core temperatures of potential fatalities were significantly higher than those of survivors of either group. Despite large differences in body weight (-25%, Table 1), run time (-37%, Table 2) and work done (-49%), there was no significant difference between the post-run core temperatures of the surviving Low K^+ fed group and the control group. This result was explained by the highly significant differences ($p < .0005$) in the average rate of heat gain (Δ Tc) per kg M of work done (Table 3). In contrast, the average rate of post-run cooling (20 minutes at 26 $^\circ$C) was identical for both groups (0.03 $\pm$ .02 $^\circ$C per minute). Thus, potassium depletion

Table 3

Effect of Low Potassium Diet on the
Core Temperature (Tc) of the Running Rat

Group	Pre-run Tc ($^\circ$C) Control	Pre-run Tc ($^\circ$C) Low K^+	Post-run Tc ($^\circ$C) Control	Post-run Tc ($^\circ$C) Low K^+	Δ Tc/kg M ($^\circ$C) Control	Δ Tc/kg M ($^\circ$C) Low K^+
Post-Run Survivors	37.9 ± 0.7	37.8 ± 0.7	40.4 ± 0.7	40.3 ± 0.7	0.05 ± 0.04	0.12*† ± 0.06
(n)	(21)	(55)	(21)	(54)	(20)	(55)
Post-Run Fatalities	38.0 ± 0.2	37.6 ± 0.8	41.8 ± 0.8	41.3*† ± 0.3	0.05 ± 0.02	0.14 ± 0.10
(n)	(3)	(15)	(3)	(15)	(3)	(15)
		Range Fatalities	40.0-42.3	40.8-41.7		

*Low K^+ values significantly different from controls ($p < .05$).

†Fatalities values significantly different from survivors ($p < .05$).

clearly predisposes to heatstroke in rats (exhaustion, collapse, high core temperatures, cell injury and sometimes death). The mortality data, furthermore, supports the concept that the heatstroke episode, when it occurs, has a greater than average mortality rate.

The muscle potassium content of sedentary, fasted rats fed the Low K^+ diet for 32 days was reduced significantly (~28%, Table 4). Statistically identical concentrations were found in the gastrocnemius muscles from both groups of post-run survivors likewise fasted a total of 48 hours (24 hours pre run plus 24 hours post run). In contrast, the respective post-run fatalities had, slightly but significantly lower muscle potassium levels than either post-run survivors or sedentary rats. Although the plasma sodium levels from post-run

Table 4

Effect of Low Potassium Diet and Exercise Hyperthermia on Rat Gastrocnemius Muscle and Plasma Potassium Concentration

Group	Muscle K^+ (mEq/g) Control	Muscle K^+ (mEq/g) Low K^+	Plasma Na^+ (mEq/L) Control	Plasma Na^+ (mEq/L) Low K^+	Plasma K^+ (mEq/L) Control	Plasma K^+ (mEq/L) Low K^+
Sedentary 48 h Fast	0.42 ± 0.01	0.31* ± 0.02	152 ± 15	150 ± 12	5.9 ± 0.6	3.1* ± 0.5
(n)	(12)	(24)	(12)	(21)	(12)	(21)
Post-run Survivors	0.44 ± 0.04	0.31* ± 0.04	144 ± 16	150* ± 12	6.3 ± 1.1	3.7*‡ ± 0.8
(n)	(20)	(55)	(19) [142][1]	(53) [138]	(19) [5.5]	(53) [2.8]
Post-run Fatalities	0.39†‡ ± 0.06	0.28*†‡ ± 0.03	156 ± 1	154 ± 7	10.6 ± 2.7	5.9*†‡ ± 2.2
(n)	(3)	(15)	(2) [192]	(8) [182]	(2) [7.4]	(8) [3.8]

*Low K^+ values (mean ± S.D.) significantly different from controls ($p < .05$).

†Fatalities values significantly different from survivors ($p < .05$).

‡Post-run values significantly different from sedentary ($p < .05$).

[1] Brackets contain predicted values based on the change in hematocrit (31).

survivors of the Low K^+ groups were slightly higher than control or predicted values, both sedentary groups exhibited normal concentrations. The postrun fatalities from both control and Low K^+ groups maintained nearly normal plasma sodium levels despite the decrease (18-21%) in plasma volume calculated by the equation of Van Beaumont et al. (30). See Table 5. Compared to control animals, all plasma potassium levels for rats fed the Low K^+ diet were markedly depressed (41-47%). As previously reported (11, 24), the agonal samples from post-run, control fatalities exhibited striking elevations in circulating potassium (80% > sedentary controls). On the other hand, values for control survivors (24 hours post-run) were not changed significantly. In contrast, plasma potassium concentration in both post-run Low K^+ groups (survivors and fatalities) were elevated significantly above resting levels.

With the exception of an initially lower plasma protein concentration in the fasted Low K^+ fed rats (Table 5), there were no significant differences in hematocrit and plasma osmolality between groups. When sampled 24 hours after exercise-induced hyperthermia, the survivors of both groups exhibited significant reductions in hematocrit and osmolality but not plasma protein. The resultant expansion in circulating plasma volume (7-9%) calculated from the change in hematocrit is consistent with a hemodilution process through protein enrichment of the intra-vascular space (note lack of change in plasma protein concentration to predicted levels). In contrast, post-run fatalities of both Low K^+ and control groups, sampled agonally, had significant increases in hematocrit indicating reductions in plasma volume from 18 to 21%. The failure of plasma protein levels to achieve concentrations predicted by plasma water loss is consistent with the movement of both protein and fluid from the intravascular compartment.

The Low K^+ diet did not result in increased urine production and, in fact, it was reduced significantly (Table 6, 24 hours fast) below control output. Continued fasting (24-48 hours), however, reduced urine volumes of control rats to Low K^+ levels probably due to the absence of prandial drinking. In contrast, although both groups increased urine production significantly following exercise hyperthermia (post-run, 48 hours fast), control volumes were 2-fold higher. The urine to plasma osmolality ratios for sedentary control and Low K^+ groups were approxi-mately 3 and 2, respectively. However, probably due to the increased urine volume of control rats, their post-run U/P ratio fell significantly. As expected from the dietary intake, the potassium concentration in the urine of

Table 5

Effect of Low Potassium Diet and Exercise Hyperthermia on Rat Hematocrit, Osmolality, Plasma Protein and Volume Change

	Hct (%)	% Δ	Hct (%)	% Δ	Pl. Osm.	(mOsm/kg)	Pl.Prot.	(g %)
Group	Control	Pl. Vol.	Low K^+	Pl. Vol.	Control	Low K^+	Control	Low K^+
Sedentary 48 h Fast	42.5 ± 2.4	--	43.3 ± 5.4	--	321 ± 6	318 ± 10	6.6 ± 0.4	6.2* ± 0.4
(n)	(12)		(26)		(12)	(23)	(12)	(25)
Post-run Survivors	40.7 ‡ ± 3.1	+ 7	41.0‡ ± 3.5	+ 9	313‡ ± 13	312‡ ± 10	6.4 ± 0.4	6.3 ± 0.4
(n)	(21)		(57)		(19)	(51)	(21)	(55)
							[6.2][1]	[5.7]
Post-run Fatalities	48.9†‡ 4.5	-21	48.7†‡ 9.1	-18	--	--	7.8†‡ ± 0.1	6.9†‡ ± 0.7
(n)	(2)		(13)				(2) [8.3]	(12) [7.6]

*Low K^+ values (mean ± S.D.) significantly different from controls ($p < .05$).

†Fatalities values significantly different from survivors ($p < .05$).

‡Post-run values significantly different from sedentary ($p < .05$).

[1] Brackets contain predicted values based on the change in hematocrit (31).

Table 6

Effect of Low Potassium Diet and/or Exercise Hyperthermia on Selected Urinary Constitutents of the Fasted Rat

Group	Volume (ml)		K^+ (mEq/L)		$\frac{\text{Urine Osm}}{\text{Plasma Osm}}$		Occult Blood (0 to 3+)		Total Protein (0 to 3+)	
	Control	Low K^+	Control	Low K^+	Control	Low K^+	Control	Low K^+	Control	Low K^+
Sedentary 24 h Fast	18 ± 8	13* ± 6	0.94 ± 0.29	0.04* ± 0.03	3.0 ± 1.2	2.4* ± 0.7	0 -	0 -	trace -	1+ -
(n)	(58)	(114)	(53)	(120)	(36)	(21)	(57)	(115)	(57)	(115)
Sedentary 48 h Fast	11† ± 4	12 ± 4	0.62 ± 0.10	0.02*† ± 0.01	2.9 ± 0.8	2.1* ± 0.7	0 -	trace -	1+ -	1+ -
(n)	(1[illegible]	(26)	(10)	(22)	(12)	(23)	(12)	(26)	(12)	(26)
Post-run 48 h Fast	38‡ ± 25	17*‡ ± 9	0.74 ± 0.32	0.05*‡ ± 0.05	1.8‡ ± 1.0	2.1 ± 0.9	3+ -	3+ -	2+ -	3+ -
(n)	(21)	(53)	(21)	(56)	(19)	(51)	(21)	(55)	(21)	(55)

*Low K^+ values (mean ± S.D.) significantly different from controls ($p < .05$).

†Sedentary 48 h values significantly different from 24 h ($p < .05$).

‡Post-run values significantly different from 48 h sedentary ($p < .05$).

the sedentary control group was 25 fold higher and there was a further reduction in the urinary potassium concentration of both groups with continued fasting (24-48 hours). Following exercise hyperthermia, there was an increased content of potassium, occult blood, and protein in the urine of both groups.

Circulating transaminases were assayed 24 hours after collapse in both groups of post-run survivors (Table 7). Plasma GOT activity had reached

Table 7

Effect of Low-Potassium Diet and Exercise Hyperthermia on Plasma Transaminase Levels

Group	Plasma GOT (IU/L) Control	Plasma GOT (IU/L) Low K^+	Plasma GPT (IU/L) Control	Plasma GPT (IU/L) Low K^+
Sedentary 48 h Fast	101 ± 71	118 ± 88	34 ± 14	25 ± 22
(n)	(12)	(24)	(12)	(24)
Post-run Survivors	2812‡ ± 2437	1142*‡ ± 1306	838‡ ± 770	463‡ ± 1232
(n)	(11)	(33)	(16)	(49)
Range	71-7563	62-5820	72-2314	36-7520
% > 1000	73%	33%	31%	8%

*Low K^+ values (mean = S.D.) significantly different from controls ($p < .05$).

‡Post-run values significantly different from sedentary ($p < .05$).

heatstroke levels (> 1000 IU/L) in 73% and 33% of the control and Low K^+ survivors, respectively. The 2-3 fold difference in activity level between glutamic oxaloacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) within each group and the similar difference in activity for each enzyme between groups probably reflects the 2 fold difference in work done before exhaustion (13, 14).

The effect of a low potassium diet and/or exercise hyperthermia on rat tissue pathology is shown in Table 8. The histological evidence indicates that under the conditions of these experiments the primary lesion induced by feeding a low potassium diet occurs in the heart and not the kidney. No histo-pathologic

Table 8

Effect of Low Potassium Diet and/or Exercise Hyperthermia on Rat Tissue Pathology

	Myocardial Necrosis		Liver Necrosis		Skeletal Muscle Necrosis		Kidney Necrosis	
Group	Control	Low K^+	Control	Low K^+	Control	Low K^+	Control	Low K^+
Sedentary	0%	90%*	0%	5%	0%	0%	0%	4%
(n)	(19)	(21)	(23)	(22)	(23)	(20)	(22)	(23)
Post-run	47%†	93%*	83%†	32%*†	26%†	8%	0%	0%
(n)	(17)	(28)	(18)	(25)	(19)	(25)	(21)	(20)

*Low K^+ values significantly different from controls (Chi-square with Yate's connection factor $p < .05$).

†Post-run values significantly different from sedentary.

changes occurred in tissues from sedentary rats fed the control diet supplemented with both potassium and magnesium. In contrast, sedentary animals fed the low-potassium diet had a 90% incidence of heart myocarditis with a very low occurrence of either liver (5%, 1 of 22) or kidney (4%, 1 of 23) lesions. While heart lesions were often noted to be subendocardial in distribution, changes often occurred in deeper portions of the myocardium. These lesions consisted of myocardial necrosis often attended by a severe mononuclear infiltrate composed largely of histiocytes. Except for frequency (Table 8), myocardial changes were identical in post-run controls, sedentary and post-run Low K^+ groups. The combined stresses of exhaustive-exercise and whole-body hyperthermia resulted in a significant hierarchy of tissue injuries with evidence of liver, heart and gastrocnemius muscle pathology in 83, 47, and 26% of post-run control rats, respectively. Liver lesions in both post-run groups consisted of mild to massive hepatic necrosis which was predominantly centrilobular in location. Skeletal muscle necrosis, when present in post-run groups, was characterized by patchy areas of necrotic fibers often infiltrated with histiocytes. Except for occasional dilation of tubules or protein casts, only one rat (sedentary, Low K^+) showed renal necrosis. In animals fed the low-potassium diet, the only significant increase in tissue lesions due to exhaustive exercise and hyperthermia was an approximately 30% incidence of liver necrosis. As indicated by both histology and serum transaminases, the reduced incidence of hepatic pathology relative to control rats (32 vs 83%) is probably a direct reflection of the shorter duration of hyperthermia in the exercised potassium-deficient rats.

Since potassium is the chief intracellular cation, a deficit of this mineral should lead to disturbances in both tissue structure and function. The more apparent and well-known symptoms of this deficiency reflect both aspects of this cellular disturbance, a failure to grow properly and a reduction in exercise endurance, (Table I and Figure 1). Moreover, inspection of Figure 1 indicates the dramatic decline in the treadmill performance of adult rats fed the low potassium diet for one month. For example, 66% of the control group (16 of 24 rats) accomplished more than 45.5 kg•M of work compared to only 6% (4 of 72 rats) of the Low K^+ group.

The histological evidence indicating a 90% incidence of myocardial lesions in the Low K^+ group (Table 8) could conceivably contribute to the observed performance decrement. Although myocardial lesions have been described in a number of species as a consequence of potassium deficiency (32), the characteristic feature is necrosis of cardiac muscle. Schrader et al. (27) found patchy myocardial necrosis, more in the left ventricle than the right. Follis et al. (8) noted that while the lesions were frequently subendocardial, they never involved the endocardium itself. According to Follis (8), the lesions first appear in the heart and kidneys but no changes were encountered in the voluntary muscles of rats. The lesions were definitely more extensive following exercise (7). Macpherson (23) demonstrated that the largest lesions are subendocardial, especially in the papillary muscles and trabeculae, and conjectured that local strain may determine its localization. He also warns that other factors can produce similar lesions (23). This caution appears justified by our own observation (Table 8) that similar lesions were found in 47% of the post-run controls. It is not known to what degree the acute lesioning process, induced by the combined stresses of exhaustive exercise and hyperthermia, shares a final common pathway with the chronic process identified with potassium depletion but the mechanisms could be similar. For example, there could be two different triggers for the intracellular release of lysosomal enzymes. Post-run controls with and without heart lesions were not significantly different in post-run core temperature, total work done or circulating potassium levels. But controls with lesions had run a shorter time before exhaustion (93 vs 126 minutes, $p < .05$) and had higher 24 hour post-run GOT levels (4173 vs 1361 IU/L, $p < .025$). Thus, the predisposition to exercise-induced heart lesions may be linked to poorer performance and higher transaminase levels.

As can be calculated from Table 4, the 32 days of feeding a low potassium diet to adult rats (250-300 g) resulted in a 47% reduction in plasma potassium levels. Although normal levels of potassium in serum may coexist with significant cell depletion, a depressed concentration in serum is usually reflective of a total body deficit (32). For example, Huth et al. (16) estimated that a serum potassium level of 3 mEq per liter in man implies a deficit of 300 to 400 mEq. The 28% reduction in muscle potassium noted in Table 4 is probably a minimum difference since we did not correct for the higher fat content per gram of muscle in control rats. The increase in circulating plasma potassium levels seen at 24 hours in post-run survivors of the low-potassium group occurred despite: 1) an additional 24 hours of fasting, 2) a lower average muscle concentration and 3) an estimated 9% increase in plasma volume (Table 5). In post-run fatalities of the low-potassium group, it should be noted that 1) there was a similarly striking increase in circulating potassium (90% > sedentary), 2) the increase was not due solely to hemoconcentration (see predicted value) and 3) this increased circulating level was identical to that found in sedentary rats fed the control diet. Thus, the finding of clinically normal potassium levels after an injury has occurred can conceal: 1) pre-existing hypokalemia, 2) the enormous increase from pre-run levels and, thereby, 3) the seriousness of the disorder.

Under the conditions of this study we were unable to demonstrate that feeding adult rats a low potassium diet for 32 days resulted in either polyuria (Table 6) or histological evidence of renal necrosis (Table 8). The lower urine volumes recorded for the sedentary Low K^+ group is presumably appropriate for a fasted rat of that weight. In fact, the only indication of altered renal function for rats fed the low potassium diet was the somewhat lower U/P osmolality ratio. Although surprising, the absence of either polyuria or renal pathology during dietary potassium restriction is not unique. In 1940, Thomas et al. (29) confirmed the presence of cardiac lesions during potassium restriction in rats but did not observe the development of lesions in the other tissues. Similarly, in the report of Coburn et al. (5) the dietary potassium restriction of human volunteers resulted in EKG changes in all subjects but no nocturia or increase in urine volumes. Appropriate thirst mechanisms were apparently operative since post-run survivors of both groups demonstrated expanded plasma volumes (Table 5) and increased urine production (Table 6) in response to exercise hyperthermia. The increased content of potassium, occult blood and protein in the post-run urine collections of both groups approximated that reported earlier (11).

In a previous experiment (11) we had observed that rats weighing approximately 500 g and run under identical conditions of treadmill speed, incline and temperature (20° C) accomplished 31 ± 10 kg•m of work, exhausted at a core temperature of $41.3 \pm 0.5^{\circ}$ C and suffered a 40% mortality rate, post-exercise. In contrast, rats run under identical conditions but at 5° C did 85% more work (56 ± 16 kg•m), exhausted at a lower rectal temperature (39.7 ± 0.7 C) with no deaths. Using these results as general criteria for this experiment, we chose to run the rats at 15° and 20° C in order to: 1) maximize potential performance differences by exercising animals under cool conditions and 2) maximize potential differences in heatstroke mortality by seeking conditions producing a relatively low incidence among control rats.

As shown in Table 2, these goals were achieved. The control survivors accomplished as much work prior to exhaustion (53 ± 20 kg•m) as slightly heavier rats run at 5° C (see above) but had a higher average core temperature at exhaustion (Table 3). As a result, there were three heatstroke deaths (3 of 24, 12.5% mortality).

By comparison, the surviving rats of the Low K^+ group (313 g), despite large differences in body weight (-25%), run time (-37%) and work done (-49%), had identical post-run core temperatures. This observation was unexpected since a lower average core temperature at exhaustion for the Low K^+ group would have been consistent with a more favorable surface area to mass ratio and work rate (~100 g lighter). As a result, the Low K^+ group demonstrated a remarkable predisposition to exercise-induced hyperthermia producing a range of core temperatures (40.8 - 41.7° C, Table 3) at which heatstroke mortality in rats usually occurs. To our knowledge, this combination of potassium deficiency and predisposition to hyperthermia has been observed in only the one human test subject reported by Coburn et al. (5). The results of this experiment, however, are certainly consistent with the hypothesis of Knochel (17) that the documented reduction in blood flow through working muscle would reduce the transfer of heated blood to the skin and, thereby, increase the rate of heat gain in the core.

Although a core temperature of 41.1° C (106° F) is often considered a threshold temperature for heatstroke diagnosis (17, 28), 46% (8 of 18) of the total number of fatalities (Table 3) had post-run core temperatures below 41.1° C. These results generally support our earlier observations (10, 12, 15) that exertion-induced hyperthermia produces a significantly higher incidence of tissue injury and heatstroke death at lower core temperatures than hyperthermia alone. On the other hand, the unique combination of lighter control rats, fed a synthetic diet for one month and subsequently run to exhaustion at 15 and 20° C has produced work outputs only previously seen with heavier rats run at 5° C (11, 15) but with evidence of cellular injury (Tables 6, 7 and 8) consistent with a core temperature at exhaustion approximately 1° C higher than observed (11, 13, 14). For example, the 3 + occult blood and 2 + total protein in the urine of control rats (T core 40.4 $\pm$ 0.7° C) noted above and in Table 6 was consistent with our prior results (11) on rats performing less work but exhausting at a core temperature above 41.3° C. Similarly the plasma transaminase levels for the post-run control rats noted in Table 7 were nearly identical to those found in rats also doing less work but exhausting a core temperature of 41.5 $\pm$ 1.0° C (13). Likewise, the incidence of elevation of plasma GOT over 1000 IU/L reported in Table 7 (73%) was consistent with a core temperature of approximately 41.5° C (14). Two explanations for this inconsistency appear possible. Since post-run control rats with exercise-induced heart lesions had higher plasma GOT levels than those which were lesion-free, the control diet could in some undisclosed manner sensitize rats to exercise-induced cellular injury. An alternative hypothesis would suggest that greater work above a threshold temperature of ~39.5° C (14), produces a greater degree of cellular injury. This latter explanation seems less likely since as noted above, control rats with no induced-heart lesions ran longer and had lower levels of circulating GOT. On the other hand, the hierarchy of tissue injury (liver > heart > skeletal muscle) noted in Table 8 appears entirely consistent with the well-described clinical picture of exertion-induced heatstroke.

In conclusion, the feeding of a low potassium diet to adult rats for one month resulted in slower growth and a remarkable reduction in running ability. The performance decrement was associated with significant reductions in skeletal muscle and circulating potassium levels. Potassium depleted rats exhibited a marked susceptibility to exercise-induced hyperthermia with evidence of increased susceptibility to heatstroke death. Dramatic post-exercise increases in circulating potassium (> 90%) in severely injured rats raised the plasma potassium to normal, control levels. Under the conditions of these experiments, heart lesions, not kidney lesions were induced by potassium depletion. Control rats exercised to exhaustion at 15 and 20° C exhibited clinical and histological evidence of a hierarchy of tissue injury (liver > heart > skeletal muscle) consistent with exertion-induced heatstroke.

Presentation:

Mager, M., R. Hubbard, G. Angoff, W. Bowers and I. Leav. The effect of potassium depletion on work performance and predisposition to heatstroke mortality. Fed. Proc. 35:2859, 1976. (Federation of American Societies for Experimental Biology, Anaheim, CA,10-15 April 1976).

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	042 Models of Heat Disabilities: Treatment and Diagnosis
Study Title:	Artificial Heat Acclimatization and the Prevention of Heat Illness. The Non-Reliability of Tail Vein Hematocrits in Fasted, Dehydrated or Heat-Injured Rats
Investigators:	Roger W. Hubbard, Ph.D. and Candace B. Kelly

Background:

In our laboratory we have been concerned with the effect of plasma volume (PV) changes on performance in the heat. An accurate and reproducible hematocrit (Hct) measurement was considered essential to aid in measuring PV changes. However, sampling site is important because there still is a controversy as to whether or not the large vessel hematocrit (LVH) is representative of the whole body hematocrit (WBH).

Several investigators used labelled red cells and albumin to measure plasma volume and red cell mass simultaneously. These values when used to calculate an "isotope hematocrit" consistently gave a lower Hct than a LVH even after the LVH was corrected for trapped plasma (x0.96). Albert (1) uses the concept of WBH<LVH as fact and cites the work of Gibson (3) as showing that organ Hcts are much lower than LVH and thus are the site of the lower Hct areas.

However, Swan and Nelson (4) concluded that the Hct of circulating blood is the same everywhere in the body. The isotope Hct is based on the assumption that the label stays in circulation or leaves at a determined rate during the measurement. Baker (2) and other authors have shown that, in any one animal, tagged albumin gives a larger PV than a larger (less permeable to the capillary wall) tagged molecule e.g. fibrinogen. These tagged molecules all give larger plasma volume values than tagged red cells which, under normal conditions, do not leave the vasculature. Too large a PV used to calculate an isotope Hct yields too small a Hct. Swan (4) also points out that the organ Hct of Gibson (3) was actually a measure of the plasma annulus around the capillaries as well as the blood in the vessels and suggests that the blood in capillaries may actually have a higher Hct than the LVH. Swan (4) was able to accurately measure a known blood loss in splenectomized dogs using tagged red blood cells and LVH (x0.96), as evidence that LVH is representative of WBH.

Progress:

To assess potential differences in large and small vessel Hct in our rats, we compared simultaneously drawn central (aortic or jugular) and peripheral (tail vein) values. As seen in Table 1 (The animals are separated into recent and older groups, because they are from different experiments.), the Hct of the larger central vessels (46 and 44 %) was lower than the smaller peripheral vein Hct (50 and 49 %). If the assumption that WBH<LVH is based on the idea of smaller vessels having smaller Hct values, it would seem that WBH is not less than LVH in the rat. We measured the Hct at the base and tip of the tail to see if there was a difference between sites on the tail itself and found no significant difference (Table 2). If plasma volume changes were calculated from the Hct differences in Table 1, the results might be interpreted as a 20% change in plasma volume when in fact the samples were drawn from the same animal at the same time.

TABLE 1

HEMATOCRIT VALUES AT DIFFERENT SITES IN THE RAT

		Central Jugular or Aorta	Peripheral Tail Vein
	N	23	25
Recent	Mean	46%	50%*
	S.D.	± 2	± 2
	N	16	50
Older	Mean	44%	49%*
	S.D.	± 3	± 2

*Tail vein value significantly different from central ($p < .05$).

TABLE 2

THE EFFECT OF SAMPLING FROM THE PROXIMAL OR DISTAL 1/3 OF THE RATS TAIL VEIN ON HEMATOCRIT

SAMPLING SITE	(N)	VENOUS HCT (%)	VENOUS PROTEIN (G)
BASE OF TAIL	12	49 ± 2	7.2 ± 0.4
TIP OF TAIL	12	49 ± 2	7.2 ± 0.4

*THERE WAS NO SIGNIFICANT DIFFERENCE BETWEEN SITES.

In other experiments on heat-induced injury in rats we have followed changes in the values of Hct, electrolytes, metabolites and some serum enzymes. The least invasive method of sampling before an experiment has been to take a tail vein sample. Then at the conclusion of the experiment, we have collected a large sample and euthanized the animal at the same time by exsanguinating the animal from the abdominal aorta. Because of the discrepancy noted above in Hct between central and peripheral sites, we decided to measure several blood parameters from the aorta, jugular and tail vein. Table 3 shows some of the differences that we found based on sample site alone. In brackets are the predicted values based on the difference in Hct. Differences noted in several values are due to expected arterial-venous (glucose, lactate) or unexpected central-peripheral (K^+, CPK, SGOT) site differences.

TABLE 3

THE DIFFERENCE IN HEMATOCRIT AND CIRCULATING PLASMA COMPONENTS BETWEEN CENTRAL (AORTIC), CENTRAL (JUGULAR) AND TAIL VEIN BLOOD SAMPLES IN FASTED RATS

	HCT %	TOTAL PROTEIN (G/DL)	GLUCOSE (MG/DL)	LACTATE (MG/DL)	K^+ (MEQ/L)	NA^+ (MEQ/L)	CPK (IU/L)	SGOT (IU/L)	SGPT (IU/L)
CENTRAL (AORTIC) N = 12	46 ± 2	6.6 ± 0.5	156 ± 33	55 ± 26	5.0 ± 1.0	140 ± 7	90 ± 40	59 ± 20	22 ± 9
CENTRAL (JUGULAR) N = 12	46 ± 2	6.4 ± 0.4	127ǂ ± 37	67 ± 29	5.1 ± 0.6	141 ± 2	92 ± 67	74ǂ ± 13	22 ± 5
PERIPHERAL (TAIL VEIN) N = 12	50*+ ± 2	7.1*+ ± 0.4	116* ± 12	25*+ ± 22	5.9*+ ± 0.6	144+ ± 2	66 ± 30	51+ ± 12	22 ± 7
		[7.4]	[174]	[62]	[5.6]	[156]	[101]	[66]	[25]

*TAIL VEIN-VALUE (MEAN ± S.D.) SIGNIFICANTLY DIFFERENT FROM AORTIC VALUE ($P<.05$).

+TAIL VEIN-VALUE (MEAN ± S.D.) SIGNIFICANTLY DIFFERENT FROM JUGULAR VALUE ($P<.05$).

ǂJUGULAR VALUE (MEAN ± S.D.) SIGNIFICANTLY DIFFERENT FROM AORTIC VALUE ($P<.05$).

BRACKETS CONTAIN PREDICTED VALUES BASED ON THE DIFFERENCE IN HEMATOCRIT.

Having established that several of the blood substances such as: Hct, protein, glucose, K^+, and lactate have significantly different values depending on the collection site, we next determined that, under experimental conditions, Hct did not change consistently peripherally and centrally. Since rats are known to be prandial drinkers, withdrawal of food could cause significant dehydration. Table 4 shows the results of collecting blood from 3 groups of rats (Fed, Fasted with water and Fasted with no water). Percent weight loss is similar in the fasted groups with and without water indicating that the animals with water but no food did not drink and voluntarily dehydrated. The Hct taken from the central sample confirms that a dehydration of 10% took place, but the tail vein Hct showed no change.

TABLE 4

EFFECTS OF FASTING (24 H) WITH AND WITHOUT DRINKING WATER ON AORTIC BLOOD VALUES AND TAIL HEMATOCRITS

	Body Wt. Loss %	Hct %	% Δ Pl. Vol.	Tot. Prot.	Osmolality (mOsm/kg water)	Na^+ (mEq/L)	K^+ (mEq/L)	Glucose (mg%)	Tail Hct %
Fed	0.4	43	-	6.5	300	138	5.0	216	49
n = 12	± 1.0	± 2		± 0.4	± 4	± 3	± 6.4	± 41	± 2
Fasted	6.1*	46	- 10	6.6	300	140	5.0	156*	50
Water	± 1.2	± 2		± 0.5	± 8	± 7	± 1.0	± 33	± 2
n = 12				[7.3]	[342]	[157]	[5.7]	[246]	
Fasted	7.1*	46	- 10	6.3	298	140	4.4*	143*	50
No Water	± 0.8	± 2		± 0.6	± 5	± 5	± 0.3	± 22	± 2
n = 12				[7.3]	[336]	[154]	[5.6]	[241]	

*Values significantly different from fed controls ($p < .05$).

Brackets contain predicted values based on the difference in hematocrit.

Exposure to heat to the point of a 4.3% loss in body weight (Table 5) caused a marked dehydration as indicated by central Hct values. In contrast the tail vein Hct decreased indicating a hemodilution.

TABLE 5

THE EFFECT OF HEATING ON TAIL AND JUGULAR HEMATOCRITS

	Jugular		Tail Vein		Wt. Loss Heating
	Hct %	Protein g/dl	Hct %	Protein g/dl	%
Fed Pre-Heat	46	6.8	49*	7.2*	—
N = 13	± 1	± 0.4	± 2	± 0.7	
Fed Post-Heat	52+	7.0	47*+	6.1*+	4.3
N = 13	± 6	± 0.8	± 3	± 0.5	± 1.8

*Tail value significantly different from jugular ($p<.05$).

+Pre value significantly different from post ($p<.05$).

Conclusion:

Thus, in conclusion, we have shown that the tail vein Hct is significantly larger than the centrally measured Hct. This is directly opposed to the WBH<LVH concept, since the LVH was 0.9 that of the tail vein Hct rather than reverse.

Since the central and peripheral Hct do not change the same way in response to experimental conditions, the indiscriminant choice of sampling site could produce completely misleading results. As a result, we use rats with chronic central cannulae to measure changes in Hct, plasma volume and other clinical indices.

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(123)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6146	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A879	BF	123
b. FORMER	6.27.77.A	3E162777A845	00	043
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)*

(U) Physical Fitness Requirements, Evaluation and Job Performance in the Army (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 012500 Personnel Training & Evaluation

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	15.0	271
	CURRENT 81	4.0	143

19. RESPONSIBLE DOD ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

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21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Physical Fitness; (U)Muscle Strength; (U)Aerobic Fitness; (U)Fitness Evaluation; (U)Job Performance; (U)Physical Training; (U)Job Tasks

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Physical fitness training programs and standards should be based on the minimum requirements commensurate with good health, appearance and MOS performance plus the added requirements of unit and mission performance. Research is needed to objectively link and translate these requirements into appropriate levels of physical fitness that can be applied to the soldier.

24. (U) Specific areas of study will include: (1) physiological demands of MOS tasks, (2) added fitness requirements for sustained operations, sleep loss and confinement, (3) development of improved body weight (obesity) standards (4) development of improved fitness screening and testing procedures and (5) physiological factors influencing lifting ability and lifting task performance.

25. (U) 79 10 - 80 09 (1) Studies were completed to identify the physiological cost (fitness demand) of groupings of MODs in terms of aerobic and muscle strength capacity. Fitness standards were derived and recommended. (2) Fitness screening methods applicable for initial MOS selection at the AFEES were developed and forwarded to DA. (3) Impact of applying gender free occupational based fitness standards was made and provided to DA. (4) New improved methods of predicting aerobic fitness were evaluated and presented to NATO study group.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043 Physical Fitness Requirements, Evaluation and Job Performance in the U.S. Army
Study Title:	Interrelationships of Isometric, Isokinetic, and Ansiometric Strength Testing
Sub-Study Title:	Comparison of Isokinetic Measurements with Test Repetitions
Investigators:	Roberta H. Mawdsley, Ed.D. and Joseph J. Knapik, SP6, M.S.

Background:

Isometric and isotonic studies have demonstrated that changes in strength can occur with test repetitions over short and long periods of time without any intervention other than the test itself (1-4). If this is true, it may be possible that isokinetic testing may demonstrate similar results. An examination of this effect if it occurs will help suggest modifications in isokinetic protocols to account for strength changes with test repetitions.

Progress:

The subjects were 12 healthy males and 4 healthy females. They were not participating in a physical training program and did not have prior experience on the isokinetic apparatus. The strength of the right knee extensors was assessed by using an isokinetic dynamometer (Cybex, Division of LUMEX, Inc., Bayshore, NY) with a modified seating arrangement. The modifications and testing techniques have been described previously (5). The subjects were familiarized with the equipment and experimental methods and were given a tour of the experimental area. After the briefing they returned to the experimental area for three sessions of testing. Two weeks were interposed between each session based on Hettinger's findings that training sessions separated by this interval do not increase muscle stength (6). During each session the subjects were positioned in the apparatus and provided with a brief re-explanation of the testing procedure. They received no warm-up trials and executed six concentric maximal isokinetic contractions (30°/second) of their right knee extensors with one minute of rest between trials. Strong verbal encouragement was given during the contractions. After each contraction they were given knowledge of the results of that trial.

The mean peak torque exerted by the total group at each of the six trials on the three sessions of testing is depicted in the figure. The first trial of session one had the highest value of the entire study. After trial one of session one the scores declined and then appeared to increase after trial three. On sessions two and three the apparent trend of the scores was reversed. The first trials showed the lowest values while the following trials were progressively higher and then reached an apparent asymptote.

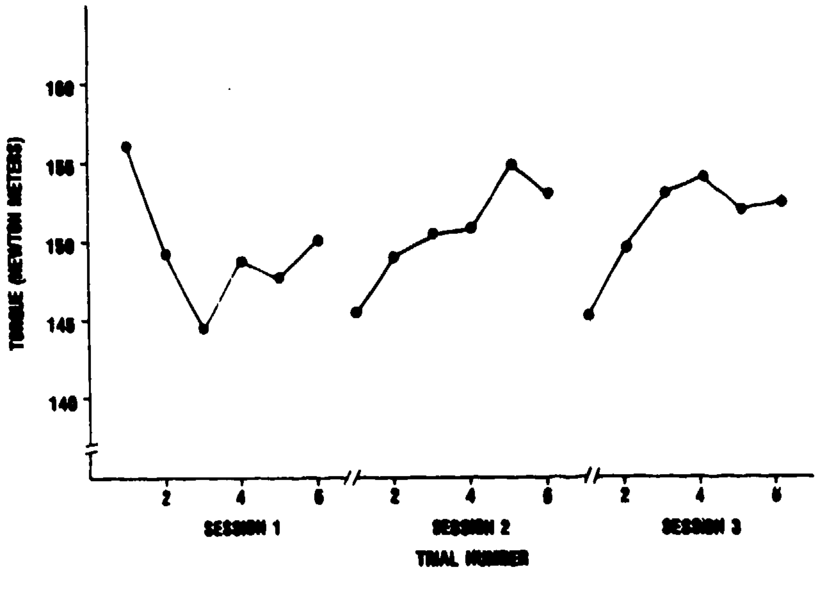

Figure 1. Mean torque scores of 16 subjects over three sessions of isokinetic testing.

A two way analysis of variance with repeated measures on the two factors of trials and sessions was performed. The main effects of trials and sessions were not significant ($p > .05$), but there was a significant interaction effect. The interaction effect indicated that the patterns of the scores within the three sessions were significantly different which is demonstrated in the figure. Trend analyses were performed to examine each pattern. These analyses demonstrated that there were significant quadratic components to the curves on sessions one and three ($p < .05$), but no significant trend occurred during session two. In session one the main effect of trials was significant ($p < .05$) which indicated that there were differences within the trials. A multiple comparison test (Tukey) indicated that trial one was significantly different than trial three with no other trials differing from each other.

The results demonstrated that an isokinetic measure of maximal voluntary knee extensor strength did not change significantly over a six week period with test repetitions. This finding differed from the results of previous isometric and isotonic studies (1-4). One possible reason why strength changes occurred in past studies was due to the close scheduling of the testing sessions. Hettinger demonstrated that a training stimuli given in a rhythm of once every week can cause a strength increase of about 40% of the increase which would have been found in daily training sessions; whereas, a two week rhythm did not show any increase (6).

The results from the statistical analyses suggest that submaximal or maximal warm-up sessions for the purpose of ensuring stability of isokinetic scores do not seem to be needed if a new subject is to be tested more than once. However, safety considerations may dictate the use of one or more warm-up trials. This finding is in disagreement with Johnson and Siegel's study which demonstrated that three submaximal and three maximal warm-up trials were necessary before the test scores were stable (7). However, their testing sessions were on three consecutive days as opposed to having two weeks interposed between each session as in this study. The statistically significant difference between trials one and three in session one suggest that if a subject is to be tested in one session only, at least one maximal trial should occur prior to recording criterion strength scores to ensure reproducible readings.

The significant quadratic component in session one and the reversal of the progression of trial scores from session one to the following two sessions may be indicative of different facilitory and/or inhibitory mechanisms occurring. After the first trial on session one all of the subjects made a comment as to the "different" feeling. As the trials progressed, most of them indicated that they were surprised or disappointed that they could not achieve a higher score on the following contractions. This subjective information seems to suggest that some inhibitory mechanism prevented them from achieving or surpassing the first score in session one. The reversal of the progression of scores in the following two sessions may be related to the fact that the subjects were experienced subjects and no longer naive concerning the "feeling" of the isokinetic apparatus.

The findings of this study with inexperienced subjects appear to suggest the following: 1) Isokinetic test scores (peak torque at 30°/second) do not change when the testing sessions occur two weeks apart from each other; and 2) if a subject is to be isokinetically tested (30°/second) on one session only, one maximal trial should occur prior to recording criterion strength measurements.

This study will be repeated with subjects who have had prior experience on the isokinetic apparatus and/or the format of this study will be utilized to compare the use of submaximal trials prior to recording criterion strength measurements.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043. Physical Fitness Requirements, Evaluation and Job Performance in the Army
Study title:	Development of MOS Fitness Standards and an AFEES Fitness Classification System for MOS Assignment Qualification (PH-2-79)
Sub-Study Title:	Development of a Fitness Test Battery for the AFEES
Investigators:	Dan S. Sharp, CPT, MC, M.D., James A. Vogel, Ph.D., James E. Wright, CPT, MSC, Ph.D. and John F. Patton, Ph.D.

Background:

In response to the General Accounting Office's directive to establish gender-free physical fitness standards for MOS qualification, the Office of the Deputy Chief of Staff Personnel (ODCSPER) tasked the Army Surgeon General and in turn this Institute to develop a battery of physical fitness tests suitable for screening new accessions for MOS classification at Armed Forces Examining and Entrance Stations (AFEES). The Exercise Physiology Division conducted two studies to accomplish this objective, the first in the Spring of 1978 at Ft. Jackson, SC and the second in the Fall of 1979 at Ft. Stewart, GA. This report presents the final analysis, conclusions and recommendations from both studies.

The basic approach in this project was to identify likely test battery items suitable for predicting both aerobic and muscle strength fitness suitable for the implementation at the AFEES. Then, through the use of multiple linear regression techniques, those test items were selected which were most predictive of two criterion measures: maximal oxygen uptake (for aerobic fitness) and maximal safe lifting capacity (for muscular strength fitness). These test items were then applied to systems which could be used to screen applicants for MOS qualification standards. Based on this analysis, final recommendations have been made to ODCSPER regarding implementation.

Progress:

1. Statistical treatment

Suitable test items were selected and prediction equations developed for each criterion capacity by using multiple linear regression techniques. Problems resulting from separate male and female populations (gender effects) were dealt with by analysis for parallel and coincidental behavior. In the case of both criterion capacities, male and female populations had the same parallel behavior (same regression slopes) but coincidence was different. This necessitated the addition of a gender factor in the final equations.

Many of the independent test item variables were found to be highly intercorrelated. This multicollinearity was dealt with by applying a ridge regression treatment, i.e., a mathematical treatment of adding bias or a constant to the correlation matrix which assists in selecting the more powerful contributors for the regression equation.

2. Aerobic capacity

Table 1 presents the data characteristics employed in developing the aerobic capacity model. This data was acquired at Ft. Jackson in new recruits and was selected from measurements in which a clear aerobic capacity (maximal oxygen uptake) was obtained. Table 2 presents the intercorrelation matrix for both criterion and predictor variables. Table 3 presents the beta weight scores from ridge regression analysis for the three available variables. The multiple correlation coefficient for these three variables with aerobic capacity was 0.839.

TABLE 1

Sample characteristics of variables used to derive the aerobic cpacity prediction model. Mean $\pm$ S.D

Variable	Females	Males
n	44	42
$\dot{V}O_2$ max, l/min	2.12 $\pm$ 0.28	3.57 $\pm$ 0.42
Step test, l/min	2.10 $\pm$ 0.37	3.27 $\pm$ 0.59
Lean body mass, kg	41.3 $\pm$ 4.46	58.9 $\pm$ 6.80
Body weight, kg	57.0 $\pm$ 6.6	70.8 $\pm$ 10.8
Age, years	19.4 $\pm$ 1.6	19.1 $\pm$ 1.8

TABLE 2

Intercorrelation matrix for criterion and predictor variables considered for aerobic capacity

	Gender	Step Test	% BF	$\dot{V}O_2$ max
Gender	1.0			
Step Test	0.448	1.0		
% BF	0.684	-0.685	1.0	
$\dot{V}O_2$ max	0.785	0.643	-0.839	1.0

TABLE 3

Unbiased standardized regression coefficients (beta weight) for aerobic capacity predictor variables - 3 variable model

Variables	Beta Weight
Gender	-0.454
Step Test	0.141
% BF	-0.417

TABLE 4

Unbiased standardized regression coefficients (beta weight) for aerobic capacity predictor variables - 2 variable model

Variables	Beta Weight
Gender	-0.467
% BF	-0.502

Initial response by the Army to the inclusion of the stepping test was negative due to time and money constraints. We thus explored the possibility of a two-predictor model. Beta weights for such a regression are given in Table 4. Correlation coefficient was reduced only to 0.821. This was judged as being acceptable. The final equation for the prediction of aerobic capacity was:

$$\dot{V}O_2\text{max (ml/kg/min)} = 68.04 - 0.573\ \%\ BF - 7.598G$$

where G represents a gender designator of '1' for males and '2' for females.

A model developed on only these two variables does igrore the aspect of "state of training" as a constituent of aerobic capacity. Thus, the model is predicated on differences due to inherent capacity, gender and body composition. The cost of adding the "state of training" component does not appear justified in the population we are dealing with.

3. Strength capacity

Table 5 presents the data characteristics employed in developing the strength capacity model. This data was acquired at Ft. Stewart in experienced soldiers from the 24th Infantry Division. Table 6 presents the intercorrelation matrix for both criterion and predictor variables.

TABLE 5

Sample characteristics of variables used to derive the muscle strength capacity model. Mean ± S.D

Variables	Females	Males
n		
MLC, kg	32.6 ± 5.5	57.4 ± 10.9
LBM, kg	45.2 ± 5.2	62.1 ± 6.4
Age, years	22.2 ± 3.0	21.1 ± 2.3
LEG, kg	100 ± 25	167 ± 44
TR	53 ± 12	80 ± 16
UT	61 ± 13	108 ± 16
HG	35.1 ± 6.3	54.7 ± 8.3
UP38	87 ± 18	140 ± 23
UP132	40 ± 10	60 ± 14

MLC: maximum lifting capacity to 132 cm, LBM: lean body mass, LEG: isometric leg extension strength, TR: isometric trunk extension strength, UT: isometric upper torso strength, HG: isometric hand grip strength, UP38: isometric upright pull strength at 38 cm, UP132: isometric upright pull strength at 132 cm.

TABLE 6

Intercorrelation matrix for criterion and predictor variables considered for muscle strength capacity

	LBM	UT	LEG	TR	HG	UP132	UP38	Gender
LBM								
UT	.80							
LEG	.49	.43						
TR	.57	.66	.33					
HG	.82	.80	.43	.58				
UP132	.65	.68	.50	.58	.63			
UP38	.81	.80	.60	.70	.77	.75		
Gender	-.75	-.75	-.48	-.58	-.71	-.53	.73	
MLC	.88	.78	.48	.52	.76	.59	.74	-.70

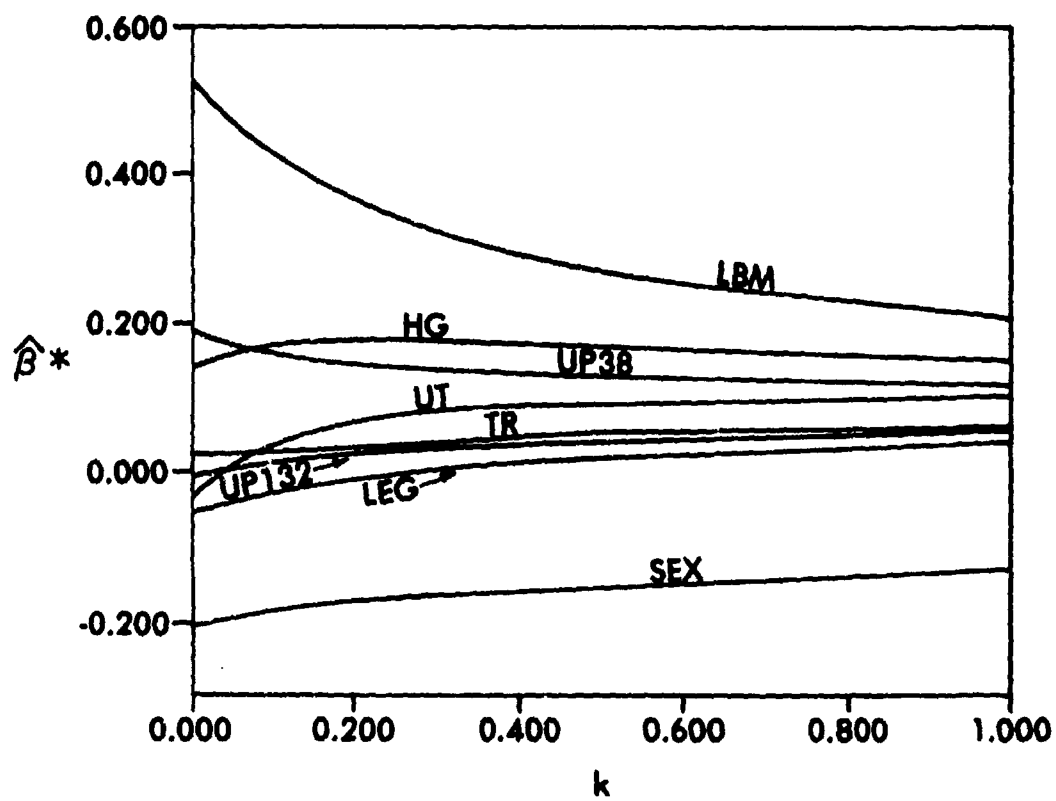

Figure 1. Variation of eight standardized regression coefficients with bias.

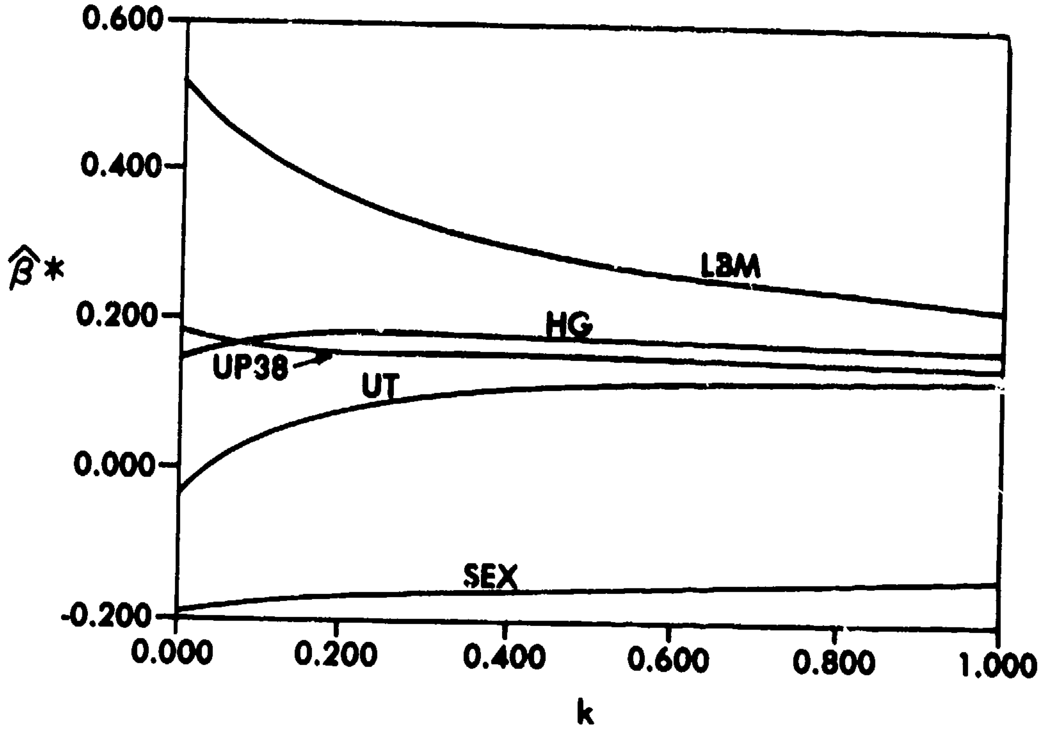

Figure 2. Variation of vie standardized regression coefficients with bias.

Figure 1 presents the beta weights from ridge regression analysis plotted against varying constants. From this analysis, we chose to drop the variables, TR (trunk strength), UP 132 (upright pull strength at 132 cm) and LEG (leg extension strength), all of which were driven relatively more rapidly to zero than the others. Figure 2 illustrates the beta weight plots with the remaining five variables. Inspection of this data suggests that the three strength measures to be similar in importance for a predictive model. Because of the operational constraints at the AFEES, it was decided to eliminate handgrip (HG) and upper torso (UT) strength as predictor variables and retain upright pull strength (UP38). The basis for keeping UP38 rested mainly on its face validity and the simplicity of the measure. Table 7 presents the final beta weights in this 3 variable model.

Multiple correlation coefficient was 0.785. The resulting equation for strength capacity was

Max safe lift to 132 cm(kg) = -8.466 + 0.993 LBM + 0.006 UP38 - 4.77G
where G represents a gender designation of '1' for males and '2' for females

TABLE 7
Unbiased strandardized regression coefficients (beta weights) for muscle strength capacity predictor variables

Variables	Beta Weights
LBM	0.546
UP38	0.191
Gender	-0.175.

Presentation:

Vogel, J. A., J. E. Wright and D. S. Sharp. Assessment of muscle strength and lifting ability upon entry into the service. NATO Research Study Group 4 (Physical Fitness) Meeting, Mainz, W. Germany, 22-26 September 1980.

Publication:

Sharp, D. S., J. E. Wright, J. A. Vogel, J. F. Patton, W. L. Daniels, J. J. Knapik and D. M. Kowal. Screening for physical capacity in the US Army: an analysis of measures predictive of strength and stamina. USARIEM Technical Report, in press.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043 Physical Fitness Level Requirements and Evaluation for the U.S. Army
Study Title:	Development of MOS Fitness Standards and an AFEES Fitness Classification System for MOS Assignment Qualification (PH-2-79)
Sub-Study Title:	Muscle Strength and Lifting Capacities of Army Enlisted Personnel
Investigators:	James E. Wright, CPT, MSC, Ph.D., Dan S. Sharp, CPT, MC, M.D., James A. Vogel, Ph.D. and Joseph J. Knapik, SP6, M.S.

Background:

Although the role of muscle strength in the total fitness required of today's soldiers remains to be completely defined, a requirement considerably above accepted industrial work classification standards has been identified as necessary for acceptable duty performance in the majority of Army military occupational specialties (13). Among the various MOS, the tasks with the most significant muscle strength demands were determined to be those involving manual materials handling, principally lifting and carrying. As part of a larger project to develop a system for matching the physical capacities and fitness characteristics of recruits with the demands of the various MOSs (8), this study was conducted to determine (a) the lifting capabilities of Army enlisted personnel, and (b) the relationship between this capacity and various simple standardized static and dynamic tests of muscle strength.

The feasibility of estimating an individual's ability to lift loads has been addressed in numerous publications (1, 2, 3, 6, 9, 10). These studies, however, have been conducted exclusively from an industrial perspective with the objective of minimizing injury incidence and optimizing efficiency of repetitive manual materials handling tasks in populations of industrial workers. The U.S. Army, which is concurrently faced with manpower shortages and ever increasing mission requirements, is also in need of achieving the best possible matching of the physical as well as the mental abilities of individuals to the demands of the various occupational specialties. In as much as both the population characteristics (age, sex, physical training status, etc.) and its mission sets the Army apart as a unique organization, it was deemed necessary, in pursuit of the above mentioned goals, to determine the lifting capacity of a representative sample of the Army enlisted personnel, and the relationship of this capacity to various static and dynamic laboratory tests of muscle strength.

Progress:

Two populations of enlisted personnel have been studied. The first consisted of approximately 50 males and 25 females who were finishing their advanced individual training (AIT) in April, 1978. All the females and half of the male soldiers were completing AIT, predominantly in an administrative or maintenance MOS, at Ft. Jackson, SC, while the remaining males were completing infantry AIT at Ft. Benning, GA. The second population was made up of approximately 200 males and 50 females assigned to the 24th Infantry Division, Ft. Stewart, GA. This latter group was older as well as more diversified in terms of rank, time in service, work experience and training status than the first group, and was probably relatively representative of enlisted personnel Army-wide. Selected characteristics of both populations are presented in Table 1.

TABLE 1

Characteristics of two sample populations studied for lifting capacity. Mean + S.E.M.

Ft. Jackson

	Male	Female	Combined Sample
N	54	25	79
Age (yrs)	19.9 + 0.3	20.6 + 0.7	20.1 + 0.3
Ht (cm)	174.3 ± 0.8	163.9 ± 1.2	171.0 ± 0.9
Wt (Total, kg)	72.2 ± 1.1	61.2 ± 1.3	68.7 ± 1.0
Wt (LBM, kg)	61.1 ± 0.8	48.9 ± 0.9	47.3 ± 0.9
BF (%)	15.2 ± 0.5	27.0 ± 0.7	18.9 ± 0.7

Ft. Stewart

	Male	Female	Combined Sample
N	221	49	270
Age (yrs)	21.1 ± 0.2	22.7 ± 0.4	21.3 ± 0.2
Ht (cm)	176.1 ± 0.5	165.9 ± 0.9	174.2 ± 0.5
Wt (Total, kg)	73.6 ± 0.6	63.5 ± 1.4	71.7 ± 0.6
Wt (LBM, kg)	62.2 ± 0.5	45.5 ± 0.8	59.6 ± 0.6
BF (%)	15.3 ± 0.3	27.9 ± 0.8	17.7 ± 0.4

Criterion Variable:

Inspection of the MOS task list (11) revealed that 90 percent or more of job tasks with strength demands exceeding minimal (Echo Cluster Baseline) requirements were characterized as being single or repetitive lifts or lift and carry performances. Therefore, a single maximal dynamic lift was selected as the criterion variable that best reflects strength demands of Army MOSs. The object selected for the test lift was a steel box (45 l x 31 w x 26 cm d) whose handles, 20 cm above the bottom of the box, were padded with foam rubber and adhesive tape. Based on current Army mobility requirements and the standardized equipment sizes (tactical vehicle size), it was decided that the box would be lifted from ground level and placed on a flat surface at a height of 132 cm (bed height of tactical 2-1/2 and 5 ton trucks).

After demonstrations and instruction concerning proper techniques, all subjects began lifting the empty box (15.6 kg). Weight was added to the box in 1.2-11 kg increments depending upon the ease with which the subject lifted the previous weight. Subjects were allowed as much time as they desired between lifts (usually 2-3 minutes).

Subjects were required to use a flexed hip-straight back technique (12). They were instructed to use one smooth motion in lifting from ground to platform. No "jerking" was allowed. The following guidelines were used by two monitoring investigators to determine when subjects had exceeded their "maximum safe lifting capacity": 1) flexing of the spine at any point during the lift, 2) degeneration of a single smooth controlled lift into disrupted segments, 3) hyperextension of the trunk in an attempt to "angle" the edge of the box onto the lip of the platform, and 4) inability to place the weighted box on the platform when proper form was maintained. Once one of these criteria had been observed, the weight lifted previously (usually 2-2.5 kg less) was identified as the individual's maximal "safe" capacity.

Potential Predictor Variables:

Five isometric strength tests were administered to the subject in the Ft. Jackson study. The body areas evaluated included the legs, trunk extensors, pulling muscles of the upper torso (in two different positions) and the grip muscles. These measures plus another isometric test involving both the legs and the upper torso and a dynamic (isokinetic) test of trunk extensor strength (at two velocities) were used at Ft. Stewart.

The equipment and procedures for the isometric tests has been described in detail in previous publications (5, 7). The dynamic strength of trunk extensor muscles was assessed on an isokinetic dynamometer (Cybex Division/Lumex, Inc., Bay Shore, NY). For this test, the subject was positioned securely in an apparatus which stabilized the thighs and hips and allowed for extension of the trunk at the axis of the iliac crest. The subject was coupled to the dynamometer lever arm with a padded cuff which was placed on the upper back and secured under the arms and around the shoulders.

The subject was instructed to extend his trunk and to exert as much force as possible backwards against the pad. The test movement began with the subject's upper torso flexed 90 degrees. Dynamic trunk strength was measured at two velocities, 36 and 108 degrees per second. In each of these tests, as in all others, strength was assessed as the mean value of three maximal contractions, conducted at approximately 60 second intervals.

In addition to the strength tests, the relationships of several anthropometric parameters to lifting capacity were also determined. These included height, total body weight, and lean body mass determined from skinfold measurements (4).

Results of the strength measurements and the lifting tests are presented in Table 2. Both groups were extremely similar as regards the laboratory strength tests. However, although the females of both populations lifted approximately the same amount, the males from the Ft. Jackson sample lifted substantially more than those from Ft. Stewart. Such findings suggest that these types of strength tests may not allow accurate prediction of specific lifting capacities. However, the relatively good Pierson Product Moment correlations between the various strength tests and lifting capacity indicate that the tests are valuable in terms of their ability to rank order individuals with respect to lifting capacity, an objective which fits perfectly the anticipated rank ordering scheme for use of such tests (J. A. Vogel, Final Report: Development of a Physical Fitness Test Battery for MOS Classification at the AFEES; Oct 80).

Figures 1 and 2 illustrate the lifting capacities of the populations sampled at Fts. Jackson and Stewart, respectively. The shapes of the distributions are relatively similar for each sex at the two locations. There is an overlap of capacities for the two sexes in both cases, albeit rather small. The major difference lies in the rightward (increased lifting capacity) shift of the entire group of males at Ft. Jackson.

Table 3 depicts the Pearson Product Moment correlations of the various strength tests with the maximal safe lift capacity. Again, the similar relationship between lifting capacity and the various tests in both sexes and in both locations can readily be observed. In both cases, the highest correlation coefficients occurred between lifting capacity and upper torso and grip strengths. The relationship between upright pulling strength at a height of 38 cm and lifting capacity was also high.

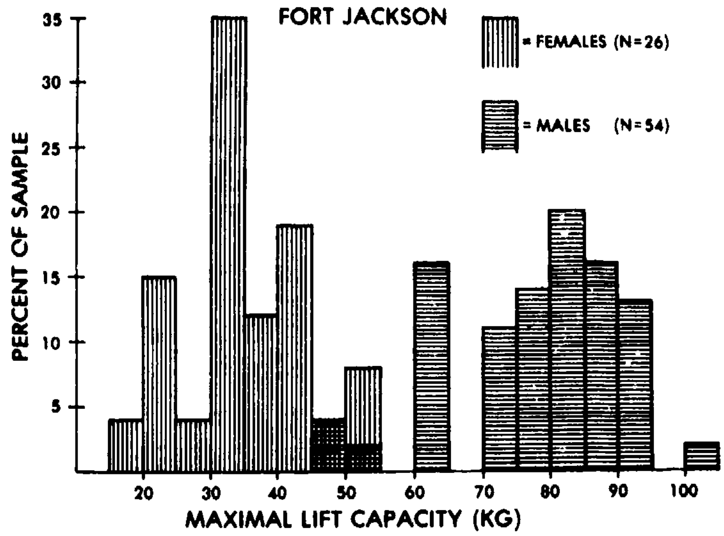

Figure 1. Distribution of maximal lifting capacities within the Ft. Jackson sample.

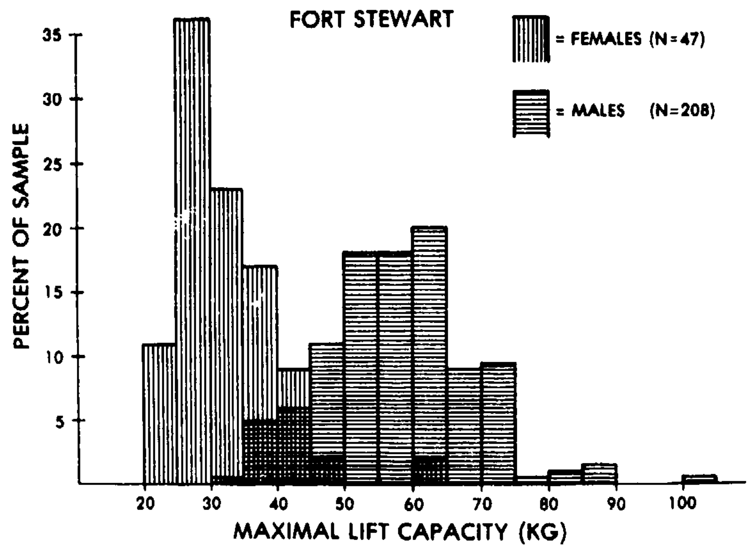

Figure 2. Distribution of maximal lifting capacities within the Ft. Stewart sample.

TABLE 2

Muscle Strength of Enlisted Army Personnel. Mean + S.E.M.

	Ft. Jackson		
Isometric Measures	Male	Female	Combined Sample
(Kg force):	(N = 54)	(N = 26)	(N = 80)
1) Upper torso	110.4 ± 2.6	60.2 ± 1.9	93.5 ± 3.3
2) Trunk	81.4 ± 2.4	60.4 ± 2.5	74.3 ± 2.1
3) Leg	159.2 ± 5.6	101.3 + 4.1	139.9 + 5.0
4) Upright pull(38cm)	---	--- ---	
5) Upright pull(132cm)	56.7 ± 1.8	36.9 ± 2.3	52.2 ± 1.8
6) Handgrip	50.3 ± 1.1	31.5 ± 1.1	45.6 ± 1.3
Isokinetic Measures (N-M force):			
1) Trunk ext. 36^{o}/sec	---	--- ---	
2) Trunk ext. 108^{o}/sec	---	--- ---	
Maximal Safe Lift Capacity (Kg)			
Ground to 132 cm	77.7 ± 1.7	35.5 ± 1.7	64.4 ± 2.6

TABLE 2 (CONTINUED)

Ft. Stewart

Isometric Measures (Kg force):	Male N = 208)	Female (N = 47)	Combined Sample (N = 255)
1) Upper torso	107.6 ± 1.1	59.6 ± 2.1	98.6 ± 1.5
2) Trunk	80.4 ± 1.2	51.5 ± 1.9	75.0 ± 1.2
3) Leg	167.3 ± 3.2	102.0 ± 4.6	154.9 ± 3.1
4) Upright pull(38cm)	138.7 ± 1.7	85.3 ± 2.8	128.9 ± 2.0
5) Upright pull(132cm)	58.9 ± 1.0	39.1 ± 1.5	55.2 ± 1.0
6) Handgrip	53.9 ± .6	34.7 ± 1.1	50.4 ± .7
Isokinetic Measures (N-M force):			
1) Trunk ext. 36°/sec	286.9 ± 5.3	163.2 ± 7.3	264.5 ± 5.5
Maximal Safe Lift Capacity (Kg)			
Ground to 132 cm	57.6 ± 0.7	32.5 ± 1.0	52.9 ± 0.9

TABLE 3

Pierson Product Moment Correlations of Strength Measures with Weight Lifting Capacity

Ft. Jackson

I. Anthropometric Measures:	Male	Female	Combined Sample
Lean Body Mass	.574	.618	.821
Total Body Weight	.494	.429	.684
Height	.421	.202	.702
% BF	-.048	-.200	-.[illegible]56
II. Isometric Measures:			
1) Upper torso	.691	.552	.907
2) Trunk	.322	-.137	.561
3) Leg	.302	.146	.645
4) Upright pull(38cm)	---	---	---
5) Upright pull(132cm)	.700	.603	.795
6) Handgrip	.527	.452	.813
III. Isokinetic Measures:			
1) Trunk extension 36^{o}/sec —	---	---	
2) Trunk extension 108^{o}/sec —	---	---	

TABLE 3 (CONTINUED)

Ft. Stewart

I. Anthropometric Measures:	Male	Female	Combined Sample
Lean Body Mass	.717	.726	.859
Total Body Weight	.652	.611	.703
Height	.498	.407	.658
% BF	.058	.034	-.502
II. Isometric Measures:			
1) Upper torso	.473	.547	.762
2) Trunk	.247	.241	.549
3) Leg	.231	.432	.509
4) Upright pull(38cm)	.466	.657	.728
5) Upright pull(132cm)	.353	.552	.580
6) Handgrip	.520	.711	.760
III. Isokinetic Measures:			
1) Trunk extension 36°/sec	.388	.374	.622
2) Trunk extension 108°/sec	.222	.359	.469

The correlations of four anthropometric parameters with lifting capacity are also presented in Table 3. In both populations, the r values for lean body mass for both sexes combined are equal to those for the strength measures.

Data described in this report was used, in part, to develop final prediction equations for lifting capacity that could be used for entrance screening. This is described in the accompanying report entitled "Development of a fitness test battery for the AFEES" by D. S. Sharp, et al.

Future Plans:

Analysis of data and development of a model to predict the capacity of females to lift the weighted box to field table height continues. Analysis of repetitive lift and carry tests conducted at Ft. Stewart also continues.

Given the potential sustained operations requirements our forces could be faced with, future plans call for more intensive research in relation to factors affecting both short and long-term self-paced work output under various conditions

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043 Physical Fitness Requirements, Evaluation and Job Performance in the Army
Study Title:	Development of MOS Fitness Standards and an AFEES Fitness Classification System for MOS Assignment Qualification (PH-2-79)
Sub-Study Title:	Energy Cost of MOS Representative Tasks
Investigators:	John. F. Patton, Ph.D., James A. Vogel, Ph.D., James E. Wright, CPT, MSC, Ph.D., Dan S. Sharp, CPT, MC, M.D. and Robert P. Mello, M.S.

Background:

In response to recommendations by the General Accounting Office, the Army Vice Chief of Staff directed the Deputy Chief of Staff for Personnel (DA-DCSPER) to establish new physical training standards based on job (MOS) requirements, regardless of gender or age. DA-DCSPER tasked the Army Surgeon General and in turn this laboratory to assist with the development of these new standards.

The general approach used to establish MOS fitness requirements was as follows:

- Step 1: Formulate physical task list for each MOS.
- Step 2: Group MOS by inspection into clusters with similar fitness demands.
- Step 3: Identify representative tasks for each MOS cluster.
- Step 4: Measure physiological Costs (energy, force) of each task.
- Step 5: Identify tasks with highest energy and force demand and establish as MOS cluster standard.
- Step 6: Convert standard from physiological units into PT test scores or training level intensities.

The first two steps in this process have been completed (Annual Progress Report, 1978, pp 211-219). This resulted in the following MOS clusters based on similarities in aerobic and strength requirements;

Cluster	Aerobic Power	Muscle Strength
Alpha	High	High
Bravo	Medium	High
Charlie	Low	High
Delta	Low	Medium
Echo	Low	Low

The entire process (Step 1 thru Step 6) has been completed for the Echo Cluster (Annual Progress Report, 1978, pp 193-200). The present report will deal with the establishment of fitness standards for the remaining four clusters.

Progress:

A research study designed to measure the energy cost demands of the representative tasks chosen for the active clusters - Alpha, Bravo, Charlie and Delta, was carried out on soldiers from the 24th Infantry Division, Ft. Stewart, GA during Sept-Oct 1979.

The most demanding tasks from job descriptions of MOS's of each cluster were chosen for energy cost measurements. The actual tasks measured were:

Cluster	MOS	Task #	Task
Alpha	11B	1	Carry 100 lb CWIE bag 1000 m in 20 min.
	51B	2	Relocate 50, 94-lb bags 20 ft in 1 hr.
	91B	3	With two person team, position on litter and evacuate 180 lb patient 250 m, 4 x per hour
Bravo	13B	4	Lift projectiles (100 lbs) from ground to 56" and carry 20 m 100x/day.
	19E	5	Lift and carry 90# ammo boxes 22 ft, 32x/hour.
	13B	6	Lift to 66" and carry projectiles (100 lbs) 5m, 3x/min for 3 min and then 1x/min for 30 min.

Cluster	MOS	Task #	Task
Charlie	62H	7	Lift and carry 94 lb bgs 10 m, 10x/15 min.
	57F	8	With 2-person team, position 180 lb remains on litter and carry 900 ft, 3x/hr for 8 hours.
	55D	9	Lift (52 in) and carry 15 m and load 55 lb projectiles, 50x/hr.
Delta	33S	10	Lift and carry 55 lb box to and from truck bed, 30x/2hr.
	54C	11	Lift and carry two 30 lb smoke pots 30 m and stack, 10x/2 min.
	76D	12	Lift and carry 60 lb containers 50 ft, 40x/hr for 8 hr.
	76X	13	Lift and carry 40 lb containers 20 ft, 60x/hr for 4 hr.

The energy cost of each of these tasks was determined by the measurement of oxygen uptake utilizing Kofranyi-Michaelis protable respiration gas meters. Only soldiers who had been serving within their MOS for 6 months and who were completely familar with the tasks to be performed served as subjects.

The energy cost data are presented in Table 1.

TABLE 1

Cluster	Tasks #	n	Wt(kg)	L/min	Kcal/min
Alpha	1	10	72.6 ± 1.8	1.66 ± 0.06	8.30 ± 0.31
	2	8	75.4 ± 3.4	0.96 ± 0.04	4.77 ± 0.18
	3	12	73.5 ± 3.2	1.62 ± 0.05	8.11 ± 0.25
Bravo	4	10	74.7 ± 1.6	0.89 ± 0.03	4.43 ± 0.17
	5	8	73.9 ± 5.0	0.75 ± 0.05	3.78 ± 0.23
	6	9	74.7 ± 2.0	1.27 ± 0.05	6.33 ± 0.23
Charlie	7	9	71.8 ± 2.3	0.88 ± 0.03	4.44 ± 0.17
	8	9	71.4 ± 2.4	1.64 ± 0.06	8.22 ± 0.28
	9	8	70.2 ± 4.2	0.75 ± 0.03	3.75 ± 0.17
Delta	10	8	75.1 ± 3.8	0.75 ± 0.04	3.77 ± 0.21
	11	9	75.9 ± 3.0	2.22 ± 0.07	11.08 ± 0.35
	12	8	72.6 ± 4.0	0.73 ± 0.03	3.66 ± 0.15
	13	8	75.7 ± 4.1	0.75 ± 0.05	3.73 ± 0.24

The tasks that were the most demanding for each cluster can be identified from the table. For the Alpha Cluster this was Task #1 ($\dot{V}O_2$ of 1.66 l/min), Bravo, Task #6 ($\dot{V}O_2$ of 1.27 l/min), Charlie Cluster Task #8 ($\dot{V}O_2$ of 1.64 l/min) and Delta Cluster Task #11 ($\dot{V}O_2$ of 2.22 l/min). Upon closer inspection of the latter two clusters, however, it is evident that the energy demands of tasks #8 and #11 far exceed the demands of the other tasks measured in the respective clusters. Thus, for Charlie Cluster it would be appropriate to place the MOS with Task #8 as one of its physical tasks, into the Alpha cluster instead of using this task to establish the Charlie cluster standard. For Delta Cluster, the energy demands of Task #11 are high because to perform it properly, the subject had to run at a very fast pace. It is questionable, therefore, how realistic this task is.

Thus, the tasks used herein to establish cluster standards were as follows:

Cluster	Task #	$\dot{V}O_2$
Alpha	1	1.66
Bravo	6	1.27
Charlie	7	0.88
Delta	8	0.75

If one assumes that the standard for each cluster should be based on an individual's ability to perform the respresentative task for 8 hours at an intensity of 45% of maximal aerobic power, then by using the equation of Bink (1), one can determine the maximal oxygen uptake required to meet the physical demands of that cluster.

Thus, the above values became:

Cluster	$\dot{V}O_2$ max (l/min)
Alpha	3.69
Bravo	2.82
Charlie	1.96
Delta	1.67

For an individual to be capable of performing adequately the fitness requirements of his/her MOS, he/she must have a maximal aerobic capacity that equals or exceeds the cluster standard to which his/her MOS belongs.

Publication:

J. A. Vogel, J. E. Wright, J. F. Patton and D. S. Sharp. A system for establishing occupational related gender free physical fitness standards. USARIEM Technical Report T3/80, 1980.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS, AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance
Work Unit:	043 Physical Fitness Requirements, Evaluation and Job Performance in the Army
Study Title:	Body Composition and Weight-Height Indices in Army Basic Trainees
Investigators:	Joseph J. Knapik, SP6, M.S., Richard L. Burse, Sc.D. James A. Vogel, Ph.D.

Background:

The Army's concern with excess weight and body fat in its soldiers is reflected in the current height and weight standards that have been established both for initial procurement (AR 40-501) and for retention in service (AR 600-9). Excess body fat is considered a serious detriment to health, longevity, stamina and military appearance.

The Acting Assistant Secretary of the Army conducted a military symposium on physical fitness during June 17-19, 1980. In his recommendations to the Assistant Secretary of Defense (MRA&L) it was suggested that body composition standards be established to replace the current weight-height tables. Also in a position paper on obesity from the Naval Health Research Center, it was recommended that research should be undertaken to evaluate the usefulness of skinfold techniques for the evaluation of body composition and population standards should be established for body fat.

In 1975 skinfold data was collected on male and female basic trainees as part of a study to determine fitness changes during training. These data have been used in this report to describe the body composition characteristics of new recruits and to provide some indication of the relationship of various weight-height indices to % body fat.

Progress:

During their first week of basic training 949 males and 499 females were tested at Ft. Jackson, SC. Weight (Wt), height (Ht) and skinfold thicknesses were measured. Weight was obtained from a digital scale and height from a fabricated free standing device. Both parameters were taken with subjects in their stocking feet wearing a T-shirt and standard issue fatigue pants. Skinfold measurements were taken with Harpenden calipers at four sites: biceps, triceps, suprailiac and subscapular. The equations of Durnin and Womersley (1) were used to obtain an estimate of % BF.

The average ($\pm$ SD) age, height, weight and % BF for various age groups are shown in Table 1. Table 2 shows the percentile rankings of these same age groups. For the males both weight and % BF increase with age. This increase is similar to that reported by Durnin and Womersley (1). For the females, however, neither the Wt nor the % BF show the increased progression with age that Durnin and Womersley (1) found. There is an increase in the oldest age group on both parameters. The females also tend to weigh less than those of Durnin and Womersley's sample (1).

TABLE 1

Anthropometric Parameters for Basic Trainees

MALES

AGE GROUP (YRS)	16.9 - 19.9	20.0 - 24.9	25.0 - 29.9	30.0 - 34.9
N	353	507	77	12
AGE (YR)	19.1 ± 0.6	21.6 ± 1.3	27.2 ± 1.5	32.3 ± 1.4
Ht (CM)	174.6 ± 6.5	174.2 ± 6.6	173.5 ± 6.8	175.8 ± 6.4
Wt (KG)	68.6 ± 10.0	71.5 ± 10.8	73.5 ± 11.4	80.9 ± 13.7
BF (%)	15.3 ± 4.7	16.1 ± 5.2	18.1 ± 5.2	22.4 ± 0.07

FEMALES

AGE GROUP (YRS)	17.0 - 19.9	20.0 - 24.9	25.0 - 29.9	30.0 - 34.9
N	148	277	60	16
AGE (YR)	19.3 ± 0.5	21.8 ± 1.4	27.2 ± 1.4	31.4 ± 1.2
Ht (CM)	163.5 ± 6.4	162.2 ± 7.1	161.5 ± 6.3	164.0 ± 6.7
Wt (KG)	59.3 ± 7.2	58.7 ± 7.1	58.7 ± 6.7	62.8 ± 8.9
BF (%)	27.7 ± 4.2	28.8 ± 4.5	28.3 ± 4.3	31.0 ± 4.8

TABLE 2

Percentile Rankings for % BF of Basic Trainees

MALES

Percentile	Age Groups 16.9 - 19.9	20.0 - 24.9	25.0 - 29.9	30.0 - 34.9
1	8.0	8.1	8.3	13.0
2	8.6	8.3	9.8	13.0
5	9.7	9.3	10.4	13.0
10	10.3	10.4	10.9	15.7
20	11.2	11.5	12.1	19.6
25	11.8	12.0	14.3	19.6
30	12.3	12.6	15.0	20.9
40	13.3	13.7	16.4	21.6
50	14.1	15.0	18.1	23.6
60	15.2	16.3	19.8	24.9
70	16.7	18.5	21.0	25.0
75	17.6	19.6	22.2	25.0
80	19.0	20.6	23.3	25.3
90	22.9	24.0	25.1	26.3
95	25.0	26.2	27.2	29.2
98	26.9	27.6	27.6	29.2
99	28.5	28.5	28.6	29.2

FEMALES

Percentile	Age Groups 17.0 - 19.9	20.0 - 24.9	25.0 - 29.9	30.0 - 34.9
1	19.6	18.3	19.0	22.1
2	19.6	19.0	21.5	22.1
5	20.6	20.3	22.2	22.1
10	21.7	22.8	22.6	24.2
20	23.9	24.9	24.3	27.4
25	24.3	25.8	24.7	27.4
30	25.2	26.3	25.6	28.0
40	27.0	27.7	26.4	29.5
50	27.5	28.9	28.1	30.1
60	29.1	30.0	29.1	33.8
70	30.7	31.3	30.6	34.9
75	31.0	32.4	31.0	34.9
80	31.5	33.2	33.2	35.5
90	32.9	34.6	34.6	36.6
95	33.8	35.5	35.7	37.2
98	36.2	36.5	36.6	37.2
99	36.7	37.4	36.7	37.2

Table 3 shows the Pearson product moment correlations coefficients between % BF and Wt and various Wt-Ht indices. When compared to the males, the correlations for the females are somewhat lower. In all age groups one or more of the indices is more highly related to % BF than is Wt alone. With few exceptions, the two indices Wt/Ht and Wt/Ht^2 show the highest correlations with % BF. Common variance (calculated as r^2 x 100%) between % BF and Wt/Ht^2 ranges from 55% to 61% for the males and 41% to 58% for the females. A previous attempt by Womersley and Durnin (2) to correlate % BF (determined from densitometry) with these same indices resulted in correlations ranging from 0.31 to 0.56 for the males and 0.54 to 0.91 for the females (ignoring the sign of the coefficient). They also found the highest correlations for the indices Wt/Ht and Wt/Ht^2.

TABLE 3

Correlation Coefficients between % BF and Various Indices

Age Group	N	Wt	Wt/Ht	Wt/Ht^2	Wt/Ht^3	$Wt^{.33}/Ht$	$Ht/Wt^{.33}$
MALES							
16.9 - 19.9	353	.72	.75	.74	.66	.65	-.64
20.0 - 24.9	507	.67	.73	.75	.70	.69	-.68
25.0 - 29.9	77	.67	.74	.78	.76	.76	-.77
30.0 - 34.9	12	.76	.78	.76	.70	.70	-.71
FEMALES							
17.0 - 19.9	148	.64	.72	.73	.65	.64	-.65
20.0 - 24.9	277	.55	.64	.64	.56	.56	-.56
25.0 - 29.9	60	.63	.69	.66	.57	.57	-.57
30.0 - 34.9	16	.66	.75	.76	.72	.74	-.76

Efforts are underway to obtain distributions of each of the component skinfolds as well as absolute BF and lean body mass for each group shown above. Similar data is available for trainees near the completion of basic training and this will be analyzed in a similar fashion.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043. Physical Fitness Requirements, Evaluation and Job Performance in the US Army
Study Title:	Evaluation of Indirect Measures of Maximal Oxygen Uptake for NATO Standardization
Investigators:	John F. Patton, Ph.D., Robert P. Mello, M.S. and James A. Vogel, Ph.D.

Background:

At the past two meetings of the NATO Panel VIII Research Study Group Four on Physical Fitness (1977 and 1979), it was resolved among member nations to try and achieve some agreement on standardizing the methodology for the measurement of aerobic fitness. While there was unanimity on the treadmill running protocol (2) as the standard for the direct measurement of maximal oxygen uptake, no concensus could be reached concerning an indirect or predictive test which could be administered to a large number of subjects in a relatively short period of time. It was agreed that the widely used Åstrand-Rhyming submaximal cycle ergometer test (1) was not very satisfactory and could be improved upon. At the conclusion of the 1979 meeting, each member nation was asked to evaluate the following two protocols for their usefulness as predictive tests of aerobic power:

1. A progressive cycle ergometer test that proceeds to maximal performance (inability to maintain pedal rate) with the end point being the greatest work load achieved. A pedal rate of 75 rpm is used with the intensity increased 37.5 watts per minute. This test is designated at NATO I.

2. The same test as above but proceeding to an endpoint of a heart rate equal to 190 - age. The endpoint is the exercise intensity achieved at the target heart rate. This test is designated as NATO II.

The purpose of this study was to evaluate the validity and reliability of these two predictive tests of aerobic power against direct measures of maximal aerobic power using both the treadmill and cycle ergometer. For comparative purposes, the submaximal cycle ergometer test of Åstrand and Rhyming (1) was also administered. This work was carried out as a cooperative effort as part of USARIEM's membership in NATO's RSG-4 on Physical Fitness.

Progress:

Fifteen male and 12 female personnel from within USARIEM were recruited to serve as subjects for this study. Each subject performed five exercise protocols which were randomly administered: maximal treadmill running test (TM), interrupted cycle ergometer test at a pedal rate of 60 rpm (CE), the NATO I and NATO II tests, and the submaximal cycle ergometer test of Åstrand-Rhyming. The NATO tests were repeated on all subjects after several days rest to determine the test - retest reliability.

The data for age, weight and $\dot{V}O_2$ max of the subjects are presented in Table 1. A relatively large range in age and $\dot{V}O_2$ max occurred for both sexes while the mean data for $\dot{V}O_2$ max was very typical for the age of the subjects.

TABLE 1

Characteristics of subjects

	Males (n = 15)		Females (n = 15)	
	$\bar{X} \pm$ SE	Range	$\bar{X} \pm$ SE	Range
Age	28.3 ± 1.4	20-41	23.9 ± 1.5	18-33
Wt. (kg)	71.9 ± 2.1	58.9-86.7	61.5 ± 2.2	49.0-81.2
$\dot{V}O_2$ max(L/min)	3.82 ± 0.13	2.96-4.62	2.73 ± 0.10	2.20-3.41
$\dot{V}O_2$ max(ml/Kg)	53.1 ± 1.5	43.0-64.7	44.7 ± 1.7	35.1-53.1

Correlation coefficients for the predictive tests and $\dot{V}O_2$ max measured directly on the treadmill and cycle ergometer are presented in TABLE 2.

TABLE 2

Correlations coefficients for Predictive and Actual Tests of $\dot{V}O_2$ max (L/min)

Predictive Test	Treadmill Male	Treadmill Female	Treadmill Combined	Cycle Ergometer Male	Cycle Ergometer Female	Cycle Ergometer Combined
NATO I	0.89*	0.88	0.92*	0.87*	0.83*	0.93*
NATO II	0.58+	0.44	0.65*	0.53+	0.38	0.62*
Åstrand-Rhyming	0.78*	0.53	0.79*	0.83*	0.58+	0.82*

+ $p < .05$; *$p < .01$

From this table it is evident that the NATO I test best predicts the actual $\dot{V}O_2$ max as measured by either treadmill or cycle ergometer for both sexes. Significant correlations also occurred with the NATO II and Åstrand-Rhyming tests and the directly determined $\dot{V}O_2$ max when the male and female data were combined. However, there is an obvious difference between the sexes in the ability of the NATO II and Åstrand-Rhyming tests to adequately predict $\dot{V}O_2$ max.

Test-retest reliability coefficients for exercise intensity (Watts) on the NATO I and NATO II test were 0.94 and 0.85, respectively, for the combined data (Table 3). In addition, the differences in the mean values for exercise intensity in watts achieved upon readministration of each teat were small and not significant.

TABLE 3

Test-Retest Reliability Coefficients

Test	Males	Females	Combined
NATO I	0.95	0.81	0.94
NATO II	0.79	0.81	0.85

All values significant at $p <$.[illegible]

The data suggest that the NATO I test is superior to either the NATO II or the Åstrand-Rhyming nomogram in predicting $\dot{V}O_2$ max determined by either the treadmill or cycle ergometer. Furthermore, the NATO I test does not exhibit a difference in its predictive capability between the sexes as appears to be the case for both the NATO II and Åstrand-Rhyming tests.

Presentation:

Patton, J. F., R. P. Mello and J. A. Vogel. Evaluation of RSG-4 Proposed $\dot{V}O_2$ max prediction tests. NATO RSG-4 Meeting, Mainz, West Germany, 24 Sept. 1980.

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(124)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION: DA OB 6142	2. DATE OF SUMMARY: 80 10 01	REPORT CONTROL SYMBOL: DD-DR&E(AR)636					
3. DATE PREV SUM'RY: 79 10 01	4. KIND OF SUMMARY: R.CORRECTION	5. SUMMARY SCTY: U	6. WORK SECURITY: U	7. REGRADING	8a. DISB'N INSTR'N: NL	8b. SPECIFIC DATA-CONTRACTOR ACCESS: ☒ YES ☐ NO	9. LEVEL OF SUM: A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A879	BB	124
b. FORMER	6.27.77.A	3E162777A845	00	045
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)

(U) Treatment of Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

002300 Biochemistry; 002600 Biology; 012900 Physiology; 005400 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	2.0	130
	CURRENT 81	2.0	30

19. RESPONSIBLE DOD ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: GADAROWSKI, John, Ph.D.

NAME: KELLY, John, D.V.M. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U)Hypothermia; (U)Hypothermia; (U)Blood Coagulation; (U)Vasodilation; (U)Angiography

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Although cold injury is of little clinical significance in the civilian community, it has had serious impact on every Army that has attempted to fight in the cold. Hospitilization times for cold induced injuries during the Korean and Second World War were 37 and 57 days respectively. Amputation and permanent loss of function and death are routine sequellae. Current knowledge suggests that increased blood flow and internal methods of rewarming, and surgical approaches to frostbite may decrease the hospitalization time and increase tissue salvage.

24. (U) An intervenous frostbite treatment solution was developed and utilized during the Korean conflict. Animal studies will be done with modifications of this formula to include more effective vasodilators to determine the effect on long-term tissue survival. Internal methods of rewarming hypothermic animals will be studied for the effects on those physiologic parameters that affect survival. Studies on blood coagulation, fibrinolysis, and platelet aggregation after different degrees of frostbite will be done.

25. (U) 79 10 - 80 09 To date changes have been observed in plasma fibrinogen, hematocrit, erythrocyte, leukocyte and platelet counts, plasma hemoglobin concentration levels and antithrombin III activity after fourth degree frostbite injury in 17 rabbits. No changes have been seen in fibrinolysis and blood coagulation. Slight changes have been observed in platelet aggregation. The study of an intravenous treatment solution for cold injury utilizing the Korean formula and the new combination is underway.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	045 Treatment of Cold Injury
Study Title:	The Alteration in Blood Coagulation, Fibrinolysis and Platelet Aggregation in Mild and Severe Frostbite
Investigator:	John Gadarowski, CPT, MSC, Ph.D.

Background:

Necrosis of blood vessels and thrombosis have been described both in human (1) and in experimental cold injury (2), but it is yet to be established whether vascular disturbances are the cause or a concomitant effect of the extravascular injury in frostbite. Evidence suggests that the blood circulation plays a decisive role in the development of tissue destruction in frostbite (3).

Very few studies have been reported dealing with measuring any changes in blood coagulation, fibrinolysis, or platelet aggregability in frostbite injury. Lepp et al. (4) measured a prolonged prothrombin time in rats exposed to subfreezing air. Barkagan and Plotnikov (5) studied 260 patients with acute frostbite injury. They found an increase in platelet aggregability and an activation of the intrinsic and extrinsic blood coagulation pathways. Chohan et al. (6) studied 15 high altitude frostbite cases at 24 hours, 4 weeks, and 1 year after injury. Reduction in platelet count, antithrombin III activity, and plasma fibrinogen level as well as increased amounts of fibrin degradation products presented evidence for intravascular coagulation 4 weeks after injury.

In our study we wanted to measure in rabbits the changes, if any, in blood coagulation, fibrinolysis, and platelet aggregation in various degrees of frostbite injury. We wanted to see what is the degree of these changes to the degree of frostbite injury.

Progress:

To date only fourth degree frostbitten rabbits have been studied. No statistical analysis of the data has been completed. Table 1 shows the hematological changes from 14 rabbits. Each rabbit was its own control. From the table platelet and leukocyte counts increase, while erythrocyte counts and hematocrit values decrease. The increase in erythrocyte and hematocrit values 1 hour after injury could be due to hemoconcentration. There is a dramatic increase in plasma hemoglobin concentration due to hemolysis caused by the freezing and thawing of the blood in the tissue. Whole blood hemoglobin is elevated 1 hour and 24 hours after injury before returning to the control values. Plasma protein concentration is elevated 10 minutes and 1 hour after injury. This change could be due possibly to the hemolysis. Plasma fibrinogen level increases 24 hours after injury. This increase in fibrinogen is due to the fact that fibrinogen is an acute phase reactant whose plasma concentration increases in association with an inflammatory stimulus (7). There is no change observed in either the intrinsic or the extrinsic coagulation system. Any increase in coagulation could have been lessened due to the observed increase in antithrombin III activity following injury. Plasma plasminogen concentration shows no decrease in its concentration following injury. The elevated euglobulin lysis time 48 hours after injury could be due to the increased concentration of fibrinogen in the plasma samples.

A second group of six rabbits was studied for in vitro changes in platelet aggregation to adenosine diphosphate (ADP) and collagen. Figure 1 shows a representative in vitro platelet aggregation curve due to ADP addition. There is a decrease in platelet aggregation and an increase in platelet disaggregation 1 hour after injury. Platelet aggregation returns to the control level by 24 hours. After 48 hours and 72 hours there is an increase in platelet aggregation and a decrease in platelet disaggregation in relation to the control. Figure 2 shows a representative platelet aggregation curve caused by the addition of collagen. One hour after injury there is no change in aggregation. At 24 hours a decrease appears followed by a return to the control range. At 72 hours there is an increase in platelet aggregation. Both figures show that there is an increase in platelet aggregation by 72 hours after 4th degree frostbite injury.

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TABLE I

Mean % Hematological changes from control values at various times after 4th degree frostbite injury in rabbits.

	Control	Mean % change from control at times after injury				
Assay	Mean (Range)	10min	1hr	24hr	48hr	72hr
WBC ($10^3/mm^3$)	7.9 (4.7-13.0) (N=14)	3 (N=7)	8 (N=13)	101 (N=14)	135 (N=11)	123 (N=7)
RBC ($10^6/mm^3$)	5.6 (4.6-6.3) (N=13)	-5 (N=6)	12 (N=11)	-9 (N=13)	-16 (N=11)	-19 (N=7)
PLATELETS ($10^3/mm^3$)	453 (357-535) (N=14)	-- --	13 (N=6)	23 (N=7)	42 (N=7)	31 (N=6)
HCT(%)	34.7 (24.8-39.5) (N=14)	7 (N=7)	9 (N=13)	-8 (N=14)	-15 (N=11)	-18 (N=7)
Hb Plasma (mg%)	1.5 (0.4-2.8) (N=14)	265 (N=13)	103 (N=14)	-3 (N=13)	-14 (N=8)	-1 (N=4)
Hb Whole Blood (gm%)	11.7 (9.5-12.4) (N=4)	-- --	13 (N=4)	17 (N=4)	4 (N=3)	0 (N=3)
PROTEIN Plasma (gm%)	4.6 (0.4-10.1) (N=10)	176 (N=5)	43 (N=9)	3 (N=9)	-6 (N=6)	9 (N=4)
FIBRINOGEN Plasma (mg%)	265 (148-366) (N=8)	7 (N=4)	9 (N=7)	49 (N=8)	102 (N=5)	184 (N=3)
Activated Partial Thromboplastin Time (sec)	15.3 (12.3-21.4) (N=10)	No Changes				
Prothrombia Time (sec)	7.7 (6.9-8.9) (N=10)	No Changes				
ANTITHROMBIN III		Increase after injury				
THROMBIN TIME		No Change				
PLASMINOGEN		No Change				
EUGLOBULIN LYSIS TIME		Increase after injury				

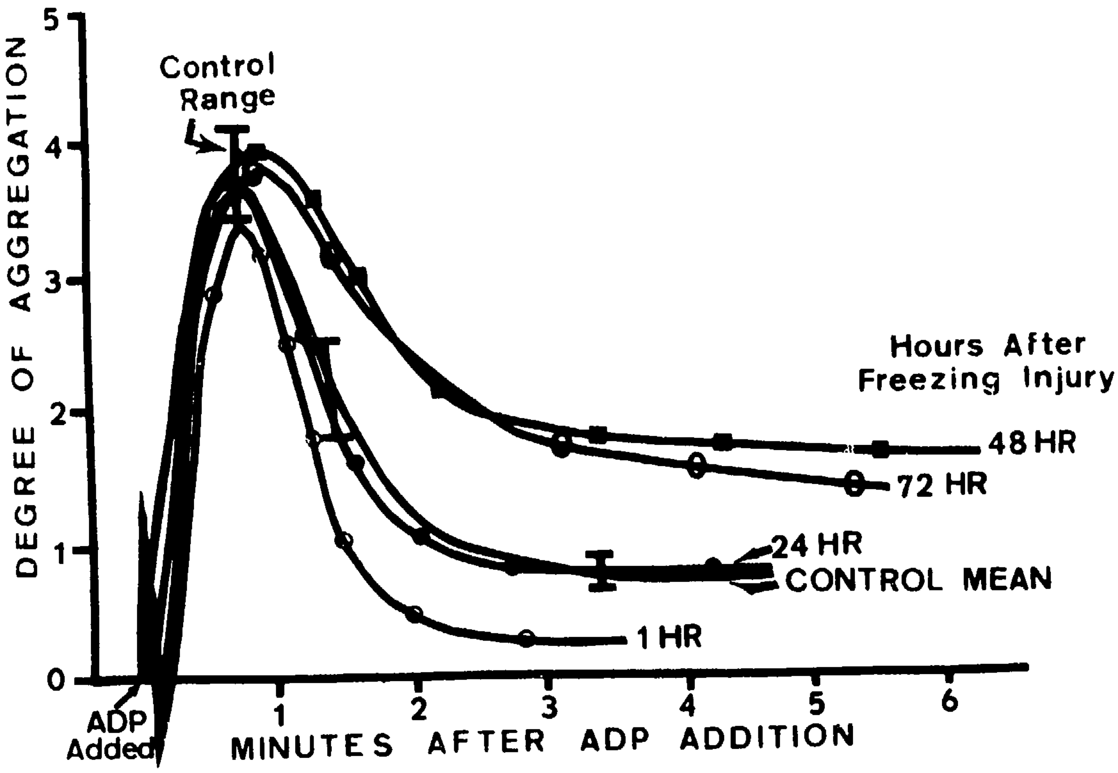

Figure 1. Platelet aggregation by adenosine diphosphate (ADP) on control and on 4th degree frostbitten rabbit at designated times after cold exposure. Control range on rabbit was done by taking at least three control determinations during the week prior to the injury.

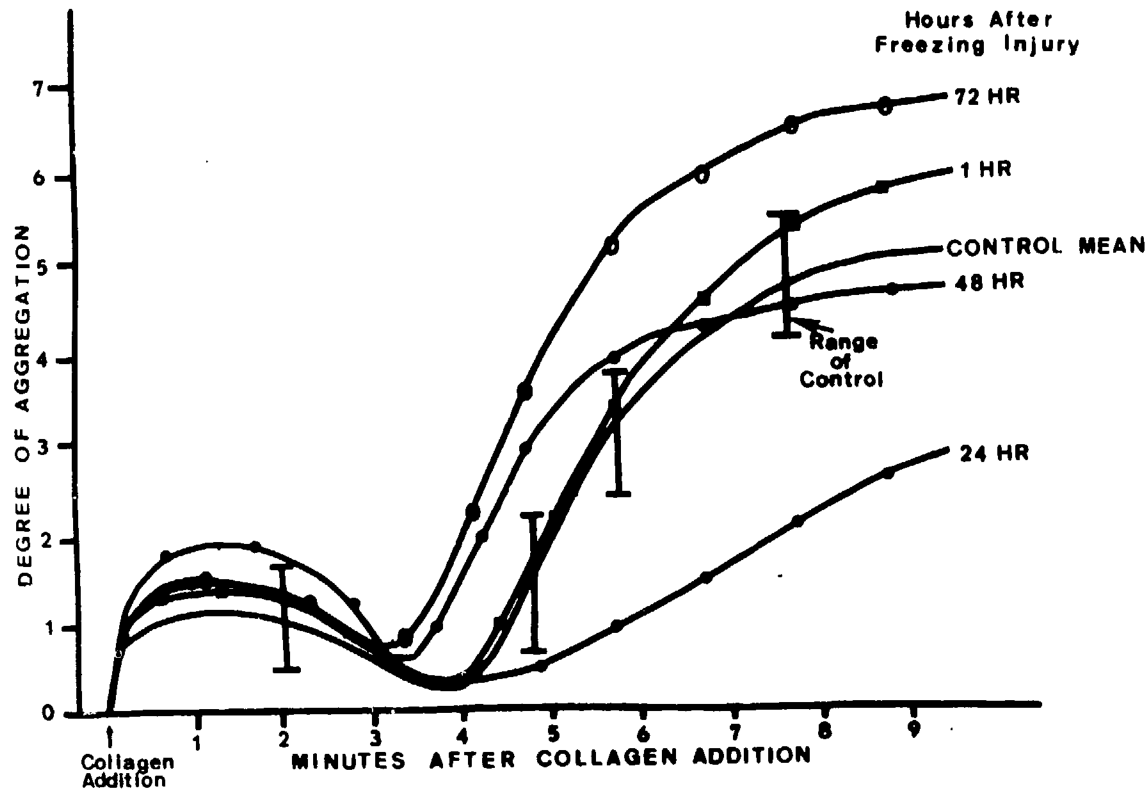

Figure 2. Platelet aggregation by collagen on control and on 4th degree frostbitten rabbit at designated times after cold exposure. Control range on rabbit was done by taking at least three control determinations during the week prior to the injury.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	045 Treatment of Cold Injury
Study Title:	Evaluation of Therapeutic Intravenous Frostbite Solution
Investigators:	John A. Kelly, MAJ, VC, D.V.M., Murray P. Hamlet, D.V.M.

Background:

An intravenous frostbite solution was described in a report of the cold injury research team Medical Research and Development Board, Office of the Surgeon General, Department of the Army (20 March 1951) (1). The mission of this team was to study the various types of cold injury occurring in the Korean theater of operations and to report the procedures found most effective in evaluation, treatment and rehabilitation of cold injury casualties. On the team's visit to the Cold Injury Treatment Center, (21 Feb 51-28 Feb 51), they discovered that an intravenous frostbite solution was recommended as part of the treatment prior to and after arrival at the treatment center. Later the use of this solution was put in a command directive dealing with cold injury problems in Korea. The formula and its recommended administration were as follows for 2nd and 3rd degree involvement:

12cc ethyl alcohol

250 mg procaine hydrochloride

5% glucose in water to make 250 cc

1. For frostbite
2. Dosage: contents of this flask (250cc), repeated every six hours for several days.
3. Instructions:
    a. Start as early as possible after each diagnosis
    b. For frostbite cases without other wounds 100mg heparin will be added to each 250cc of solution prior to the administration (2).
4. Caution:
    a. Use only the 23-gauge needle provided with the set.
    b. In doubtful cases heparin will be used only at the discretion of the local medical officer.

There is nothing in the literature on how this formula was derived, nor its actual results as a treatment. Work at this laboratory and elsewhere indicates that there are two major injuries associated with frostbite (3,4). The first is the physical effect of the ice crystal formation within the tissue and the second is a microvascular stasis that occurs within a short time after the thawing procedure (3,5,6,7,8). The subsequent cessation of nutrive flow contributes substantially to the overall destructive process of frostbite necrosis (9). It is suspected that the therapeutic value of this solution lies within the vasodilatory property of alcohol and procaine and the anticoagulant effect of the heparin promoting microcirculation. This study will be undertaken to see what degree of therapeutic results can be achieved with this solution.

Progress:

This protocol has not been started at this time except that a technique for the placement of a jugular catheter has been developed which will be used to administer the intravenous solution. It will be started after the completion of the protocol entitled, "Theramographic Evaluation of Experimentally Produced Cold Injury of Rabbit Feet" so that the results obtained from this study will be available to determine the effectiveness of this treatment solution.

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(081)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OC 6149	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 30	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A878	AE	081
b. FORMER	6.27.77.A	3E162777A845	00	046
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)* (U)Prevention of Military Environmental Medical Casualties by Epidemiologic Research and Information Dissemination (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 013400 Psychology; 022400 Bioengineering; 013300 Protective Equipment; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
74 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	2.5	55
	CURRENT 81	1.7	61

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: PEARLMAN, ELIOT J., LTC, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* PEARLMAN, ELIOT J., LTC, MC

TELEPHONE: 955-2811

SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: GOLDMAN, Ralph F., Ph.D.

NAME: VOGEL, James A., Ph.D. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Military Operations; (U)Performance Limits; (U)Military Tactics; (U)Environmental Medicine

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Identify environmental medicine problems in Army units as research requirements. Maintain dialogue with DA staff and line to (a) communicate research results to potential users, (b) provide assistance and resolve difficulties in interpreting and applying research, (c) identify unsolved problems. Provide a continuing source of identified, in-depth expertise on the impact of physiological and psychological status; military clothing and equipment; natural and crew compartment environments; high terrestrial elevations; and physical fitness on the soldier's health and mission capability.

24. (U) Maintain direct liaison with DA schools, line and staff units by visits, conferences, and correspondence. Maintain reference files on climate, clothing, and equipment, and physical and physiological differences among military populations, as a base for predicting environmental impact and mission capability. Assist in preparation of training films, TB MEDs, FMs, and other doctrine; provide consultation to units planning military operations under stressful conditions; assist with doctrine for physical training and/or acclimatization.

25 (U) 79 10 - 80 09 Briefings of military units concerning prophylaxis and therapy for the climatic stress of heat and cold have continued and presentation at civilian institutions have furthered transfer of relevant information between USARIEM and civilian organizations involved in common research efforts. Similarly, briefs and consultations with major Army commands, e.g., TRADOC, FORSCOM, have provided expertise and recommendations concerning military problems related to fitness and readiness.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	046 Prevention of Military Environmental Medical Casualties by Epidemiologic Research and Information Dissemination
Study Title:	Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination
Investigator:	Eliot J. Pearlman, LTC, MC, Research Staff, USARIEM

Background:

The research efforts of USARIEM are directed toward insuring that line components of US Forces can accomplish their missions despite the impact of climatic stress. One aspect of this work is comprised of a highly competent and talented, multi-disciplinary scientific staff providing most current and accurate information emphasizing the prevention of casualties due to environmental extremes.

Another equally important effort is translation of new information, comments and recommendations to those most directly concerned, i.e. US active duty, Reserve and National Guard units. To accomplish this, efforts are directed toward: 1) predeployment briefings of military units; 2) briefings for major Army Commands and Army Staff, (e.g. TRADOC, FORSCOM, HSC, DCSPER, DCSOPS)to provide expertise and recommendations for military problems, related to physical fitness, training and readiness; 3) consultation with Reserve and National Guard units and, 4) consultation with civilian research and academic institutions to transfer relevant and current research data and information.

Progress:

Attempts to effect current and updated mission related technology transfer to military users have continued.

There were 23 consultations requested of The USARIEM STAFF from various major Army Commands and Army Staff Agencies. Additionally 64 briefings and lectures were given at various locations throughout CONUS and Europe.

(125)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6147	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A879	BF	125
b. FORMER	6.27.77.A	3E162777A845	00	047
c. XXXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)* (U)Physical Fitness Training and Prevention of Injuries Related to Training (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 012500 Personnel Training & Evaluation

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:*
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	2.0	146
	CURRENT 81	4.0	136

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* VOGEL, James A., Ph.D.
TELEPHONE: 955-2800
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: DANIELS, William L., CPT, MSC
NAME: JONES, Bruce, CPT, MC DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Muscular Strength; (U)Physical Fitness; (U)Training Injuries; (U)Aerobic Power; (U)Physical Training

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Army physical fitness training doctrine is based largely on outdated information and has been slow in adopting new scientific concepts. Physical training in the Army could be made more effective and efficient by appropriate research to meet the Army's needs with this new knowledge and obtain new information in specific areas relevant to the Army (women, older age) where information is lacking.

24. (U) Specific studies will include: (1) Determine the optimum mode, frequency, duration and intensity of training for different applications or needs; (2) Identify differences between men and women, if any, in the qualitative or quantitative response to training; (3) Establish suitable training programs for older age groups in the Army and (4) Document incidence of sports/training injuries and seek their prevention.

25. (U) 79 10 - 80 09 (1) Different modes of muscle strength development have been evaluated and compared: isometric, isokinetic and isotonic. Greatest forces were elicited with isometric contractions. Isokinetic torques decreased with increasing velocity at most locations in the range of motion. Peak torque of the knee extensor muscles occured at 110-120 degrees. For knee flexors peak torque occurred at 140-160 degrees. (2) Research studies are presently undeway to relate physical training injuries to status of muscle strength, flexibility, anatomical allignment and anthropometric measures. (3) A study has been planned and scheduled to evaluate high intensity, continuous circuit strength training as a means to develop aerobic, anaerobic as well as muscle strength fitness.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS, AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	047 Physical Fitness Training and Prevention of Injuries Related to Training
Study Title:	The Interrelationship of Isometric, Isokinetic, and Anisometric Strength Testing
Investigators:	Joseph J. Knapik, SP6, M.S., James E. Wright, CPT, MSC and Roberta Mawdsley, Ed.D.

Background:

In a memorandum from the Office of the Deputy Chief of Staff for Personnel dated 25 Jul 77, the Army Surgeon General was tasked to develop a fitness test battery that could make possible more effective personnel acquisition and utilization (1,2). USARIEM, in constructing the test battery, realized that muscular strength is considered an important component of physical fitness and is necessary in many Army MOSs. Thus, in the early phases of the development of the test battery, a static (isometric) test of three major muscle groups was developed (3). Implicit in this particular test was the assumption that static strength measures could be acceptable predictors of both the static and dynamic tasks the military personnel are required to perform.

However, on a more basic level the relationship between strength measured in static and dynamic testing modes has not been adequately assessed. The currently available published literature shows no general agreement due to a lack of standardization of instruments, motivational techniques, criterion measures, and instructions (4). Two schools of thought have developed. One, presented by Henry and co-workers (5-8), reports poor to moderate relationships between "strength in action" and isometric strength. It concludes that strength is highly task specific due to basic differences in physics and the physiology of isometric and dynamic contraction. Their results suggested that the specificity of movement and neuromuscular coordination involved in the different tests precludes prediction in one mode from force capabilities measured in another mode. On the other hand, several other studies (9-12) have demonstrated a moderate to high relationship among strength testing modes although no physiological explanation currently exists to explain these results.

It is generally agreed that human muscular strength can be operationally defined as the ability of a muscle group to exert a maximal force in a single voluntary effort. Of the three testing modes currently available for assessing muscular strength, one (isometric) holds the muscle length constant, another (isokinetic) holds the velocity of the contractions constant, and the third (anisometric, conventionally called isotonic) holds the resistance constant while allowing the muscle length and contractile velocity to vary in a ballistic manner. This study attempted to describe the degree of relationship between these three modes of testing. A secondary objective was to examine the relationship between strength measured at various points in the range of joint motion in a single test mode.

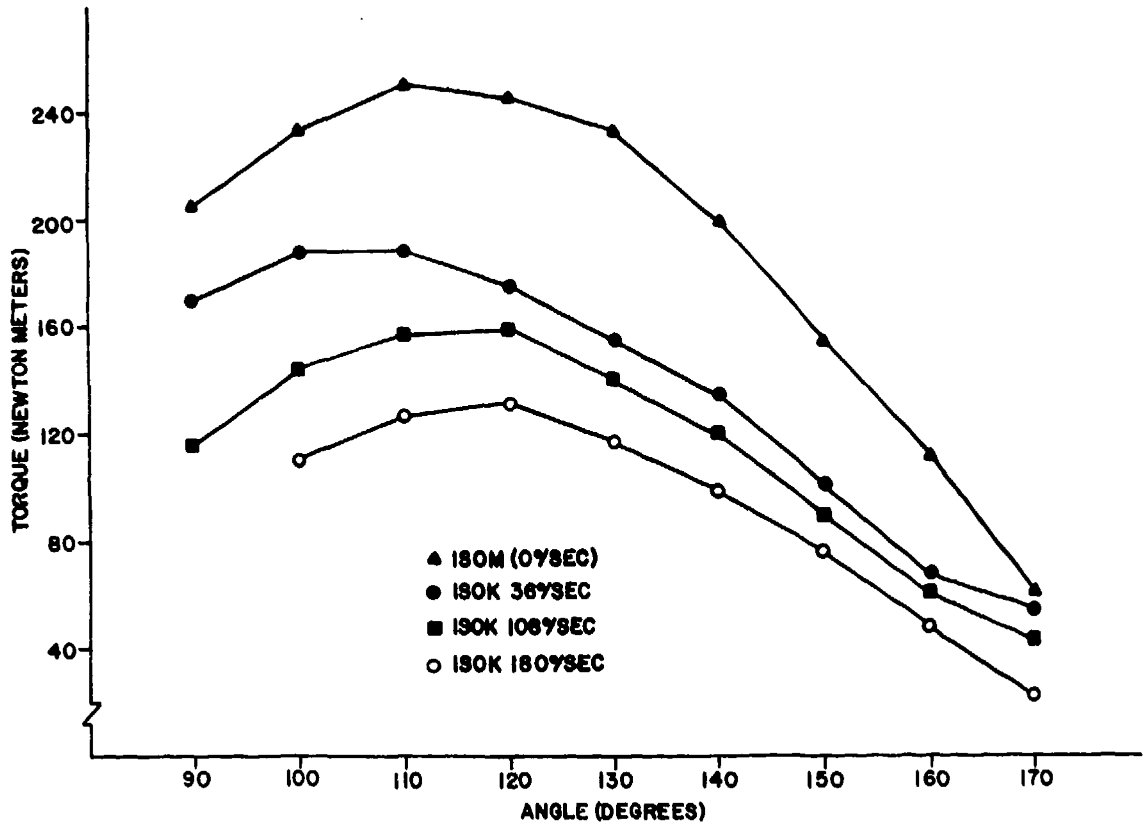

Figure 1. Isometric (ISOM) and isokinetic (ISOK) torque variations through a range of joint motions of the KE.

Progress:

Sixteen male soldiers volunteered for this study which was conducted over a six week period in February and March, 1979. During the first and the sixth week, various anthropometric parameters were obtained from the subjects and these are presented in Table 1. Percent body fat (%BF) was obtained from four skinfolds using the equations of Durnin and Wormersley (13). Lean body mass (LBM) was calculated from %BF. There were no significant changes between these two test sessions.

TABLE 1

Anthropometric Parameters
(values represent means ± SD)

	First Week	Sixth Week
Age(yrs)	26.1 ± 3.8	
WT(kg)	73.5 ± 13.8	74.1 ± 13.5
HT(cm)	174.6 ± 7.3	174.5 ± 7.2
%BF	16.2 ± 3.8	16.1 ± 4.6
LBM(kg)	61.3 ± 9.6	61.8 ± 9.1

During the second to the fifth week subjects were tested one day per week on one of four muscle groups. The muscle groups were the knee extensors (KE), knee flexors (KF), elbow extensors (EE), or elbow flexors (EF). Strength for a given muscle group was assessed in all three testing modes on the same day. The isometric and isokinetic tests were performed on a modified Cybex apparatus and the isotonic tests were performed with a unit constructed in this laboratory (14). The isokinetic tests were performed at three different velocities, 36^{o}/sec, 108^{o}/sec, and 180^{o}/sec. For the isometric and isokinetic tests, strength was recorded every 10^{o} in the range of joint motion for the KE and KF; for the EE and EF, strength was recorded at 60^{o} and 70^{o} and every 20^{o} thereafter. An electrogoniometer (15) was used to monitor the joint angle.

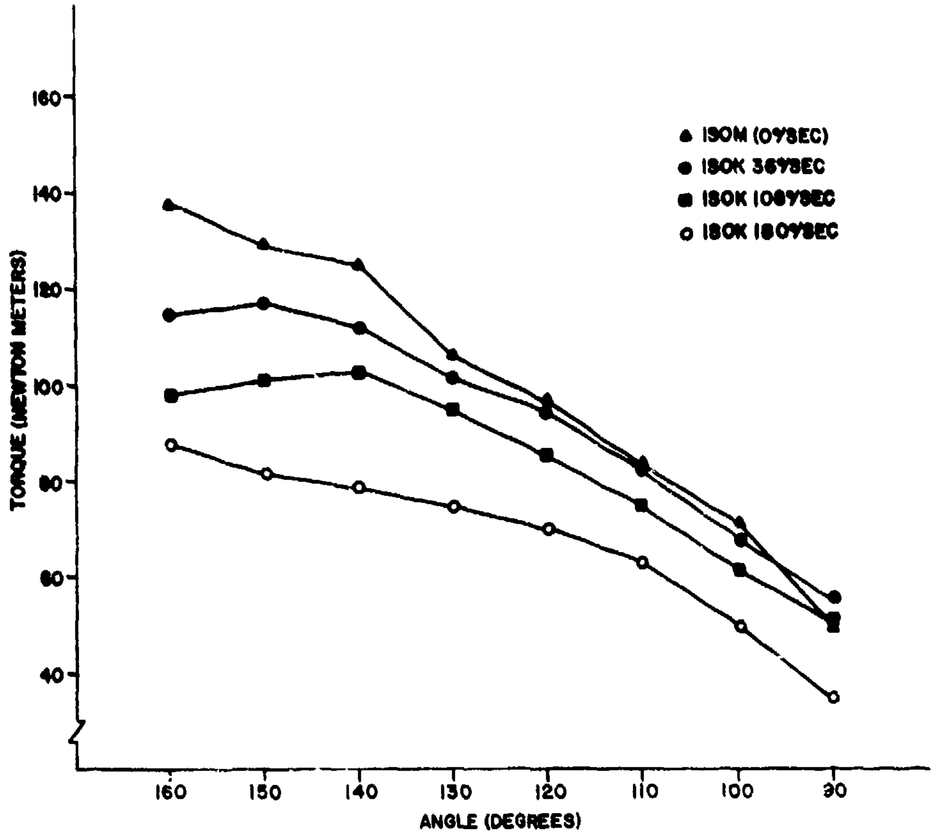

Figure 2. Isometric and isokinetic torque variations through a range of joint motion of the KF.

The variations in isometric and isokinetic torque through a range of joint motions in the four muscle groups are shown in Figures 1 through 4. In most cases, the isometric torque was the largest. The isokinetic torques decreased with increasing velocity at most locations in the range of motion. It was not possible to obtain isotonic torque curves because of methodological problems. In moving a fixed resistance through a range of motion the load experienced by the subject varied as a function of acceleration of the load. Since subjects varied in terms of the amount of acceleration, it was not possible to accurately reproduce the isotonic torque.

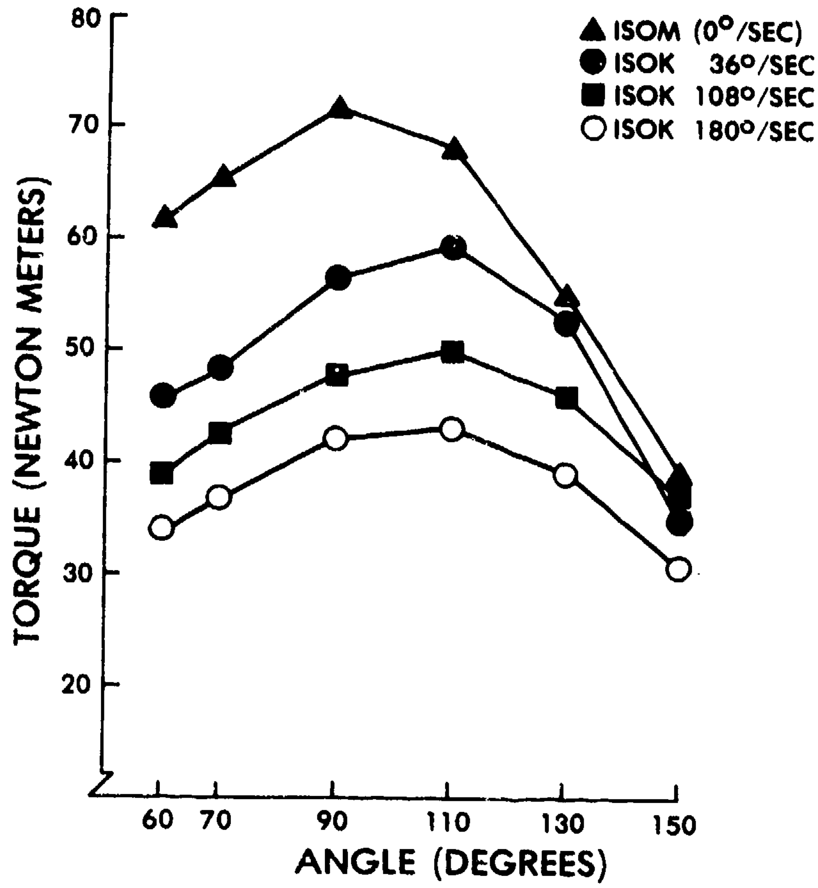

Figure 3. Isometric and isokinetic torque variations through a range of joint motion of the EE.

Figure 1 shows that for the KE, the isometric torque and the torque at 30°/sec rise to a peak at about 110° and fell off gradually thereafter. Peak torque at 108°/sec and 180°/sec occurred at 120°. There were no significant differences between the torque at 110° and 120° either isometrically or at 108°/sec and 180°/sec. At 36°/sec there were no significant differences between 100° and 110°, but 110° and 120° did differ. For the KF (Figure 2), peak isometric torque was recorded at the earliest measurable point in the range of motion, 160° but varied for the isokinetic tests. However, no significant differences were found in any of the isokinetic tests among angles 140° to 160°. For the EE and EF (Figures 3 and 4), respectively, the isometric torque was greatest at 90°. For the three isokinetic tests, peak torque occurred at 110°. For the EE, there were no significant differences between the 90° and 110° angle in any testing mode. This was also true for the EF except at the 180°/sec velocity where a significant difference existed.

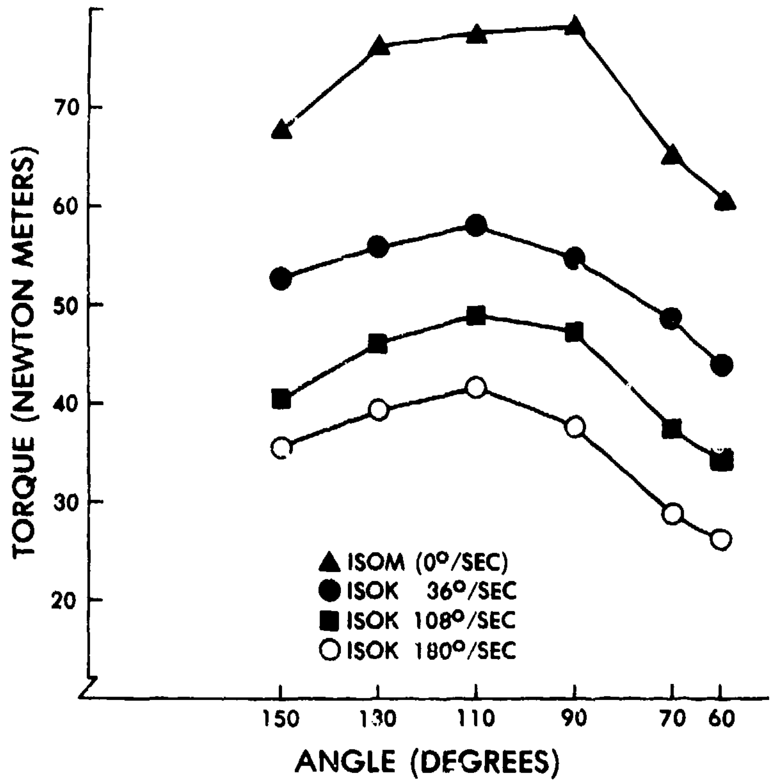

Figure 4. Isometric and isokinetic torque variations through a range of joint motion of the EF.

The intercorrelations of the three testing modes at the angles of peak isometric torque are shown in Table 2. Correlations for the KF were somewhat lower and more variable than for the other muscle groups. The KF movement was unfamilar to many subjects and this may have influenced the values obtained. However, Table 2 indicates that the correlations were larger within the various isokinetic velocities than between the isometric and isokinetic testing modes. The correlations between the isotonic test and other two modes were somewhat smaller and more variable especially for the KF. Considering the isometric test as a zero velocity isokinetic test, it can be seen that the correlations decreased as the isokinetic velocities became more widely separated. This was not true for the EE in the isometric mode. With some variations, similar relationships were found at all but the most extreme angles. For example, Table 3 shows some arbitrarily selected angles for the four muscle groups.

TABLE 2

Correlations Among the Four Testing Modes at the Angle of Peak Isometric Torque

		ISOM	36°/sec	108°/sec	180°/sec
KE(110°)	36°/sec	.83			
	108°/sec	.82	.95		
	180°/sec	.71	.80	.86	
	ISOT	.74	.89	.90	.84
KF(160°)	36°/sec	.80			
	108°/sec	.79	.78		
	180°/sec	.49*	.49*	.73	
	ISOT	.56	.47*	.71	.76
EE(90°)	36°/sec	.86			
	108°/sec	.88	.96		
	180°/sec	.90	.95	.97	
	ISOT	.77	.64	.56	.56
EF(90°)	36°/sec	.82			
	108°/sec	.80	.90		
	180°/sec	.75	.87	.91	
	ISOT	.67	.87	.80	.77

*not statistically significant at .05 level.

TABLE 3

Correlations Among the Four Testing Modes at Arbitary Selected Angles

		ISOM	36°/sec	108°/sec	180°/sec
	36°/sec	.66			
KE(150°)	108°/sec	.82	.68		
	180°/sec	.70	.60	.57	
	ISOT	.82	.77	.75	.68
	36°/sec	.90			
KF(130°)	108°/sec	.81	.88		
	180°/sec	.80	.81	.81	
	ISOT	.59	.34*	.29*	.64
	36°/sec	.81			
EE(150°)	108°/sec	.76	.90		
	180°/sec	.78	.79	.85	
	ISOT	.67	.52	.62	.51
	36°/sec	.82			
EF(150°)	108°/sec	.73	.87		
	180°/sec	.39*	.66	.75	
	ISOT	.79	.86	.72	.69

*not statistically significant at .05 level.

Tables 4 and 5 depict the correlations within each muscle group, isometrically and isokinetically (36°/sec), respectively. Generally, it can be seen that as the joint angles become farther apart, the correlations declined.

TABLE 4

Intercorrelations of Torque Values in the Isometric Testing Mode

		90°	100°	110°	120°	130°	140°	150°	160°
KE	100°	.92							
	110°	.83	.93						
	120°	.66	.78	.87					
	130°	.63	.71	.82	.94				
	140°	.52	.60	.76	.92	.97			
	150°	.48	.57	.66	.81	.92	.92		
	160°	.41	.48	.66	.79	.86	.92	.90	
	170°	.03	.08	.30	.50	.60	.73	.64	.75
		160°	150°	140°	130°	120°	110°	100°	
KF	150°	.88							
	140°	.84	.84						
	130°	.83	.86	.83					
	120°	.72	.86	.68	.86				
	110°	.65	.82	.63	.84	.93			
	100°	.56	.68	.54	.77	.88	.80		
	90°	.31	.43	.34	.43	.62	.56	.76	
		60°	70°	90°	110°	130°			
EE	70°	.98							
	90°	.96	.97						
	110°	.94	.91	.97					
	130°	.90	.83	.88	.93				
	150°	.80	.70	.69	.73	.91			
		150°	130°	110°	90°	70°			
EF	130°	.82							
	110°	.79	.98						
	90°	.71	.95	.98					
	70°	.43	.78	.77	.86				
	60°	.97	.98	.99	.99	.99			

Thus, strength testing modes were moderately to highly interrelated when the same muscle group was measured at the same angle in the range of motion. Within the same testing mode, strength was highly related at closely adjacent angles, but this relationship decreased as the angles became more widely separated.

A manuscript is in preparation, and no further investigation along this line is planned.

TABLE 5

Intercorrelations of Torque Values In Isokinetic Test Mode at 36°/sec

		90°	100°	110°	120°	130°	140°	150°	160°
KE	100°	.93							
	110°	.87	.96						
	120°	.80	.89	.96					
	130°	.80	.84	.93	.96				
	140°	.77	.82	.90	.96	.96			
	150°	.65	.68	.80	.88	.91	.92		
	160°	.40	.34	.44	.64	.69	.80	.84	
	170°	.76	.51	.51	.68	.76	.89	.45	.97

		160°	150°	140°	130°	120°	110°	100°
KF	150°	.95						
	140°	.87	.95					
	130°	.79	.88	.95				
	120°	.69	.77	.85	.94			
	110°	.55	.61	.71	.86	.95		
	100°	.16	.19	.33	.53	.65	.80	
	90°	.09	.12	.24	.42	.57	.72	.96

		60°	70°	90°	110°	130°
EE	70°	.96				
	90°	.94	.91			
	110°	.67	.89	.95		
	130°	.54	.78	.79	.83	
	150°	.73	.62	.58	.47	.75

		150°	130°	110°	90°	70°
EF	130°	.92				
	110°	.89	.99			
	90°	.82	.92	.93		
	70°	.83	.94	.95	.96	
	60°	.89	.95	.95	.98	.98

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(082)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OA 6123	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R. CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A878	AE	082
b. FORMER	6.27.77.A	3E162777A845	00	048
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)* (U)Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 013300 Protective Equipment; 022400 Bioengineering

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
64 01	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	9.0	320
	CURRENT 81	9.0	491

19. RESPONSIBLE DOD ORGANIZATION

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

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NAME:

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Tolerance Prediction; (U)Protection; (U)Biophysics; (U)Thermal Exchange; (U)Insulation(clo); (U)Evaporative Cooling Index; (U)Moisture Permeability Index

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Study energy exchanges in Man-Clothing-Environment system, to provide basis for improving thermal protection and recommending crew environments in military vehicles.

24. (U) Analyses of materials, uniforms and/or equipment using heated "sweating' flat plates, manikins, etc. indicate their effects on heat and moisture exchange and aid in predicting the user's physiological responses. Results provide guidance for military designers and identify stressful items or environments. Findings may be verified on soldiers in chamber or field studies.

25. (U) 79 10 - 80 09 Field studies on combat vehicle crewmen wearing NBC protective clothing in an XM-1 tank have clearly demonstrated the need for auxiliary personnel cooling to prevent heat collapse when operating in hot environments with the vehicle hatches closed. Copper manikin studies of auxiliary cooling provided by air cooled garments and vests covered with packets of ice have indicated the potential benefits and limitations of such systems for alleviating heat stress. Measurements of dead space volumes and breathing resistances of the XM-29 and M25A1 respirators for Chemical Systems Laboratory, Army Armament Research and Development Command have been completed. Copper manikin measurements of insulation and vapor transfer characteristics of firefighter's clothing, Air Force women's uniforms and Air Force flight clothing were performed for Army and Air Force developers. A wettable cover concept for preventing heat stress in Navy carrier personnel wearing impermeable CW protection is being evaluated.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Determination of Active Deadspace of the XM29 and M25A1 Masks
Investigators:	Clement A. Levell and Leander A. Stroschein

Background:

The Military Ergonomics Division was requested by the US Army Armament Research and Development Command, Chemical Systems Laboratory at Aberdeen Proving Ground to determine dead space and inhalation-exhalation resistance of the XM29 and M25A1 gas mask systems. The results of these tests are necessary to satisfy the Required Operational Characteristics (ROC) requirements, as established by the Test Integration Working Group (TIWG). The evaluation procedures were requested to emulate those of Cummings and Craig (1).

Progress:

This study was done in two parts. Part 1 was to determine the static deadspace and Part 2 was to determine the dynamic deadspace.

Part 1, Determination of Static Deadspace

The XM29 and M25A1 masks in three sizes were placed on the head of the Air Force copper man and filled with water. The head and mask were weighed before and after filling to determine the static volume of the deadspace. The procedure was simple, but to obtain and maintain a water-tight seal was not. The XM29 mask has a double-gasket seal and for the most part a watertight seal can be maintained. The water injected was measured, and the weight difference of the head and mask were used to calculate the volume of water injected. Three trials were made for each mask size. The masks were removed and dried after each trial. Figure 1 graphically shows the results of the nine trials.

The M25A1 did not have a sealing gasket, so watertight seals were impossible. In order to achieve a nearly watertight seal, doublesided tape was applied to the inner perimeter of the mask, and the contact surface of the head was overlaid with double-sided tape. Then the outer perimeter of the mask was taped to the head with waterproof plastic tape. In spite of all the tape, the seal was not watertight and enough leakage occurred during filling so that the volume of water injected could not be used as a comparison with weight difference. Only the weight difference could be used to determine the volume of injected water. To account for the leakage of water the head was placed in a basin on a digital scale, then water was injected and the total weight recorded. The head with filled mask was removed from the basin leaving the basin plus water leaked from mask. The weight of the basin plus water and the dry weight of head and mask were subtracted from total weight to give the volume of water in the mask. Figure 2 graphically shows the results of five trials on each mask. Due to the difficulty experienced in obtaining seals on these masks, the masks were not removed after each trial, but were only removed between the third and fourth trial.

The calculated mean volumes of the XM29 mask for small, medium, and large sizes were 581 ml, 658 ml, and 639 ml respectively. The calculated mean volumes of the M25A1 mask for small, medium, and large sizes were 412 ml, 482 ml, and 468 ml respectively. Analysis of variance showed no difference between the medium and large for either mask, but showed that the small size is significantly different for both masks.

The volume of the nose cup in each mask was measured by filling them with water. Figures 3 and 4 graphically show the results of three consecutive trails on each XM29 and M25A1 nose cup, respectively. All attempts to fill only the nose cup with the mask on the copper head ended in failure. After the active deadspace phase the nose cups were removed from the masks and individually placed on the copper head again attempting to obtain a nose-cup volume.

The following results are for completely filling the nose cups. The calculated mean volumes for XM29 small, medium, and large sizes were 125 ml, 155 ml, and 168 ml respectively. The calculated mean volumes for M25A1 small, medium, and large sizes were 145 ml, 164 ml, 181 ml respectively. Analysis of variance showed that nose cups of the XM29 mask were significantly smaller than those of the M25A1, and that the nose cups were all significantly different from each other.

Part 2. Determination of Active Deadspace

Six volunteer test subjects wore each mask of every size at six work rates. The subjects were selected by their normal mask size, so that there were two subjects for each mask size.

Work rates were attained with a treadmill set at a constant speed of 1.6 m/s, and at time intervals shown in Table I the grade was changed by 5% increments from 0 to 20%. A 30-second sample period occurred during the last 30 seconds of each time interval. The 10 and 20% grade work sessions had two consecutive 30 second sample periods. During the 30 second period the inspired and expired flow rate, nose-cup pressure, and CO concentration in the nose cup were measured at intervals of 20 milliseconds. Data was acquired with a computer controlled data acquisition system, and all data were stored in digital form. The analysis of the data is currently in progress.

TABLE I

Work Rate Intervals

time interval (min)	speed (m/s)	grade (%)
2.0	0	0
2.5	1.6	0
2.0	1.6	5
3.0	1.6	10
2.0	1.6	15
3.0	1.6	20

It is too early to report results from the data analysis, but there are problems with the XM29 mask. All subjects commented on the pungent odor of the XM29 canister. One subject did five work periods and then refused to do any further work with the XM29, but volunteered to do additional work sessions with the M25A1 mask. Four subjects strongly complained about the odors, but completed all the required work sessions. One subject considered it an annoyance. All subjects considered the mask with a single canister heavy, and much too heavy with double canisters. The straps on the mask has too much stretch allowing the mask to bounce away from the face, which broke the seal, especially during heavy work. Straps broke several times during the study. The seal on one mask developed a break in the inner gasket.

The XM29 masks used in this study were mechanically inadequate for use in the field or laboratory, and certainly would not be adequate for combat conditions.

LITERATURE CITED

1. Cummings, E. E. and F. N. Craig. "Dead space of the M9A1 and E13R9 protective masks". Chemical Warfare Laboratory Report 2264. 7-12, 1958.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Auxiliary Cooling by Liquid and Air Ventilated Systems: Phase I (Copper Man Assessment) (ME-E3-79)
Investigator:	George F. Fonseca, M.S.

Background:

Biophysical studies investigating the merits of various auxiliary cooling systems are in progress to provide a technical basis for selecting an auxiliary cooling system for combat vehicle crewmen. One method of providing temperature controlled cooling to these combat vehicle crewmen is to use water-cooled undergarments having a continuous flow of cold water through their tubing. Another possible method is to use an air-cooling system that will circulate air that is temperature and relative humidity regulated. In this phase an air-cooled vest was used to circulate cool air over the torso area of the life-sized, sectional manikin. All of these auxiliary cooling systems require a continuous source of energy and some form of connecting hoses or lines. An alternative auxiliary cooling system is the ice packets vest. This vest contains a number of ice packets positioned on the vest which provide cooling over the torso.

Progress:

Water-cooled undergarments

The auxiliary cooling provided by five water-cooled undergarments was directly measured on a life-sized, sectional manikin. Each water-cooled undergarment was worn with a combat vehicle crewman (CVC) ensemble with or without a complete chemical protective (CB) suit. Cooling rates (watts) were determined for both dry (non-sweating) and completely wet (fully sweating) skin conditions. These cooling rates are equal to the difference between the electrical watts supplied to a manikin section(s) when water is flowing through the tubing of a water-cooled undergarment and the electrical watts supplied when water is not flowing through the tubing. That is, the heat removed from the torso by the water flowing through the tubing of the water-cooled vest is equal to the watts of cooling provided over the torso by the water-cooled vest. The total watts removed from all six manikin sections (head, torso, arms, hands, legs and feet) when water was flowing through the tubing of a water-cooled undergarment was also determined. These total heat exchange rates included the cooling provided by a water-cooled undergarment plus the heat transfer from the manikin surface and the hot environment. These rates were dependent upon the clothing ensemble worn and the hot environment in which the exposure occurred.

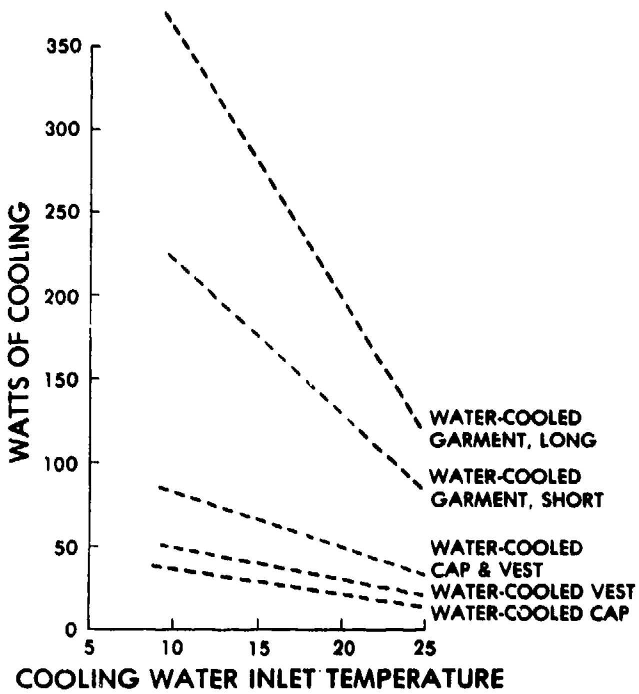

Figure 1. Watts of cooling provided by each of the five water-cooled undergarments as a function of the cooling water inlet temperature for a dry (non-sweating) skin condition.

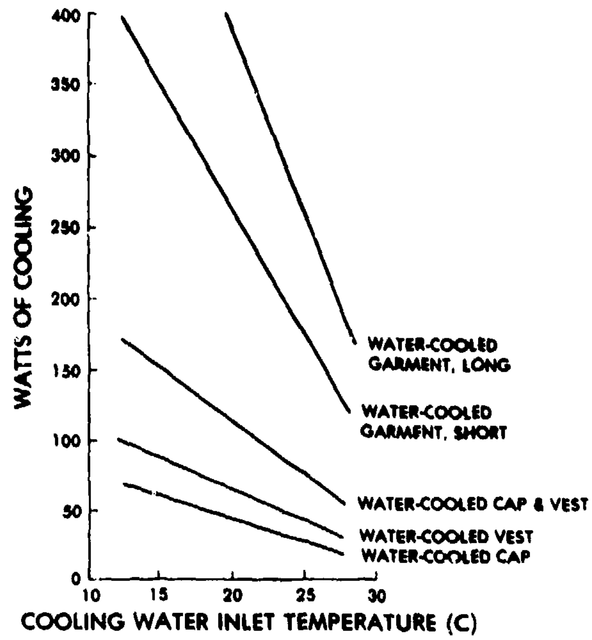

Figure 2. Watts of cooling provided by each of the five water-cooled undergarments plotted against the cooling water inlet temperature for a completely wet (fully sweating) skin condition.

Figure 1 (for the dry skin condition) and Figure 2 (for the completely wet skin condition) give the range of cooling for each of the five water-cooled undergarments versus the cooling water inlet temperature. These curves showed that at cooling water inlet temperatures above 10° C, the water-cooled cap does not provide 100 watts of cooling even for a completely wet skin condition; the water-cooled vest would require a completely wet skin condition; and the water-cooled cap w/water-cooled vest could provide 100 watts of cooling for even a dry skin. With the water-cooled undergarment, short, the skin would have to be completely wet for it to provide 400 watts of cooling, but the water-cooled undergarment, long, could provide this amount of cooling even if the skin were dry.

A cooling water inlet temperature of 20° C should provide 46 watts of cooling using the water-cooled cap; 66 watts using the water-cooled vest;

112 watts using the water-cooled cap w/water-cooled vest; 264 watts using the water-cooled undergarment, short; and 387 watts using the water-cooled undergarment, long. The results show the obvious - cooling increases with an increase in body surface area that is covered by a water-cooled undergarment. However, these calculations do not show the practical result, that the greater the skin area covered by a water-cooled undergarment, the less the area exposed to receive heat from a hot environment. These heated areas could produce hot spots over a body.

The total heat exchanges over the completely wet surface of the head, torso, arms, hands, legs and feet when water is flowing through the tubing of a water-cooled undergarment are presented in Figures 3 and 4. Figure 3 gives these total heat exchanges in watts as a function of the cooling water inlet temperature when each of the water-cooled undergarments is worn with the combat vehicle crewman ensemble in an environment of 29.4^{o} C, 85% relative humidity, Part A; and in an environment of 51.7^{o} C, 25% relative humidity, Part B. Figure 4 gives similar curves when the combat vehicle crewman ensemble is worn with the closed chemical protective suit. These curves in Figures 3 and 4 differ from the cooling curves presented in Figures 1 and 2 in that the total heat exchange curves include the cooling provided to the manikin surface by a water-cooled undergarment plus the heat transfer between the manikin surface and the hot environment. These total heat exchanges are dependent upon the clothing ensemble worn and the hot environment in which the exposure occurs. The difference between the total heat exchanges calculated for the two hot environments decreases with an increase in skin area covered by a given water-cooled undergarment; that is, the contribution to the total heat exchange (sum of the environment heat exchange and water-cooled undergarment cooling) of a water-cooled undergarment increases with increasing skin surface area covered.

The expectation that more insulation over a water-cooled undergarment would increase its effectiveness in cooling the skin surface is not evident from these experimental results. The data for the combat vehicle crewman ensemble is essentially equivalent to the data for the combat vehicle crewman ensemble with the closed chemical protective suit. The increase in insulation (1.4 clo) when the chemical protective suit is added over the combat vehicle crewman ensemble does not significantly influence the quantity of cooling provided to the area of the skin covered with a water-cooled undergarment. This finding occurs with either a dry (non-sweating) or completely wet (fully sweating) skin surface.

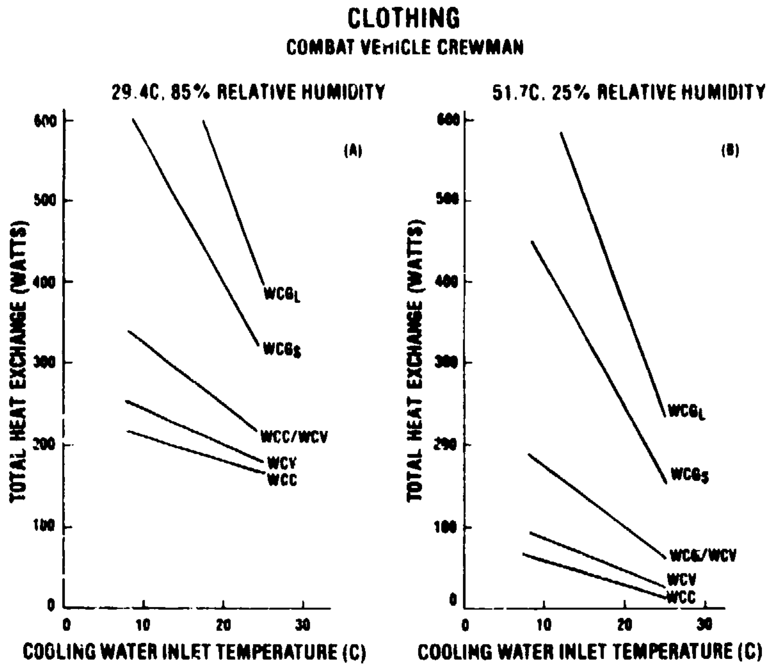

Figure 3. Total heat exchange (watts) over the completely wet (fully sweating) skin surface area (1.79 m^2) when each of the five water-cooled undergarments is worn with the combat vehicle crewman (CVC) ensemble in chamber environments of 29.4°C, 85% relative humidity (A) and 51.7°C, 25% relative humidity (B).

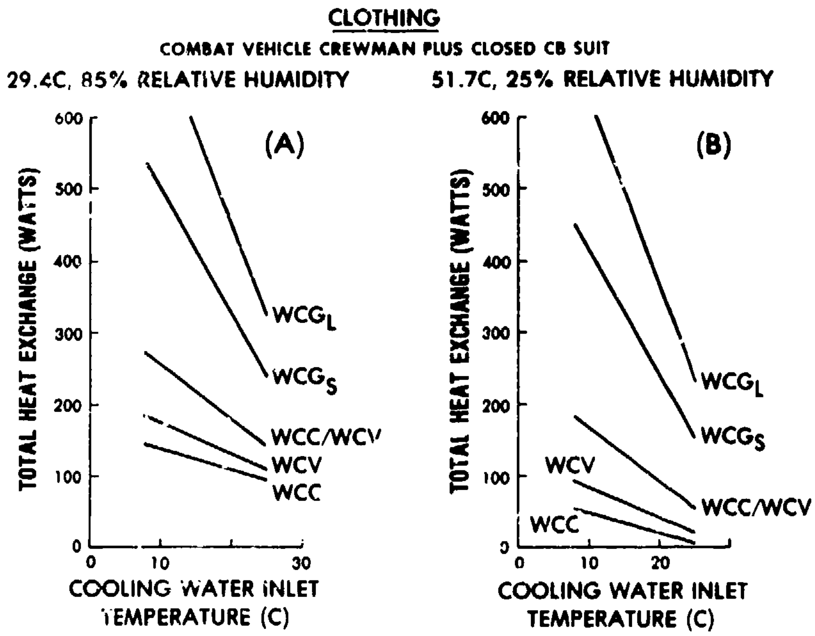

Figure 4. Total heat exchange (watts) over the completely wet (fully sweating) skin surface area (1.79°C) when each of the five water-cooled undergarments is worn with the combat vehicle crewman (CVC) ensemble w/closed chemical protective (CB) suit in chamber environments of 29.4°C, 85% relative humidity (A) and 51.7°C, 25% relative humidity (B).

These five water-cooled undergarments separately or in combination have the potential to remove the metabolic heat produced in the sedentary state (about 80 watts) or in the highly active state (about 400 watts).

Air-Cooled Vest

In our continuing experimental investigation of various auxiliary cooling systems, a hot environment study was initiated using an air-cooled vest to distribute cool air within the combat vehicle crewman (CVC) ensemble worn with a complete chemical protective (CB) suit. Air flows supplied to the air-cooled vest were 6, 8 and 10 ft^3/min and air inlet temperature to the vest was either 10^o C or 21^o C. The cooling provided by the ventilated air supplied to the air-cooled vest is given in Table 1 for exposure to a chamber environment of 29.4^o C, 85% relative humidity. These results are for a completely wet (fully

TABLE 1

HEAT EXCHANGED FOR AN AIR-VENTILATED VEST WORN WITH THE COMBAT VEHICLE CREWMAN ENSEMBLE (CVC) w/THE COMPLETE CHEMICAL PROTECTIVE (CB) SUIT FOR A COMPLETELY WET (FULLY SWEATING) MANIKIN SURFACE AT 35^o C

Chamber Environment: 29.4^o C, 85% Relative Humidity

VENTILATING AIR INLET TEMPERATURE	FLOW RATE (ft^3/min)	AIR VENTILATED COOLING (watts)	TOTAL HEAT EXCHANGE (watts)
10.0^o C	6	95	169
(20% Relative	8	137	211
Humidity)	10	158	233
21.1^o C	6	82	156
(10% Relative	8	120	194
Humidity)	10	137	211

sweating) manikin surface at an average skin temperature of 35^o C. As expected, cooling increases with an increase in air flow and a decrease in ventilating air inlet temperature. This air ventilated cooling varies from about

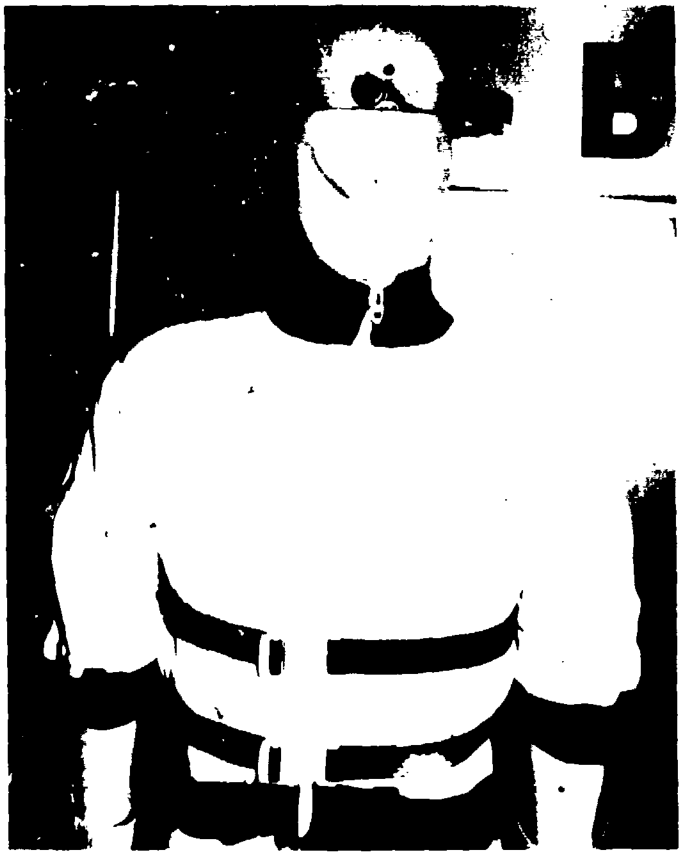

Figure 5. Photographs of the ice packets vest open (A) and dressed on the manikin (B).

53% to 68% of the total heat exchange over the manikin surface (head, torso, arms, hands, legs and feet). Measurement of the ventilated cooling provided by this air-cooled vest during exposure to a 51.7^{o} C, 25% relative humidity environment is in progress.

Ice Packets Vest

The ice packets vest is an alternative auxiliary cooling system. This auxiliary cooling system does not require a continuous source of energy or any umbilical connections, but has the disadvantage that it does not provide continuous, controlled cooling to the wearer. It provides a high initial rate of cooling which tapers off to zero cooling with continuous use. During its operating lifetime, however, it can provide cooling to a combat vehicle crewman independently of any vehicle energy. It thus has specific application for short sorties from fixed bases.

The ice packets vest used in this study is shown in Figure 5. This vest holds 72 ice packets which vary slightly in size and water content, and are secured to the vest by Velcro tape. This vest was worn with a combat vehicle crewman (CVC) ensemble plus a complete chemical protective (CB) suit. Figure 6 shows the decrease in cooling from time 0 minutes, when the ice packets vest is dressed on the manikin, in each of three chamber environments. These cooling watts are equal to the net heat removed from the torso by the ice packets vest. They are the difference between the electrical watts supplied to the torso when the ice packets vest is worn with frozen ice packets and the electrical watts supplied to the torso when only the combat vehicle crewman (CVC) plus the complete chemical protective (CB) suit is worn. It is evident from Figure 6 that the environmental conditions have an effect on both the cooling provided by this ice packets vest over the torso and the time this cooling is being provided. In environments of 29.4^{o} C, 85% relative humidity and 35.8^{o} C, 62% relative humidity, this ice packets vest is still providing some cooling after about four hours of operation. However, in an environment of 51.7^{o} C, 25% relative humidity, any benefit from wearing this vest is negligible after about three hours of operation. When 40% of the ice packets are removed from the vest, the cooling provided over the torso is negligible after about two hours of operation.

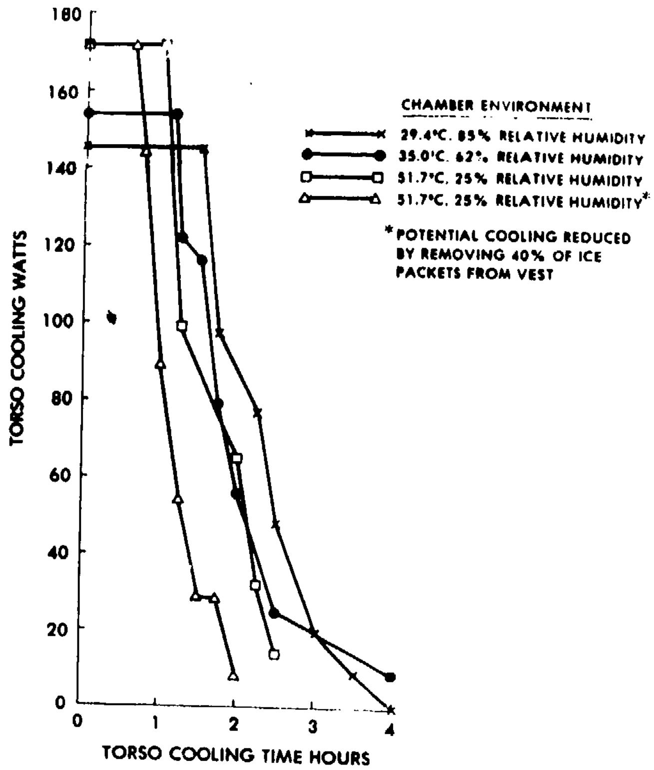

Figure 6. Torso cooling watts versus torso cooling time for the ice packets vest dressed over a completely wet (fully sweating) manikin skin.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Australian Military Clothing (ME-E5-79)
Investigators:	Clement A. Levell and Ralph F. Goldman, Ph.D.

Background:

In line with the policy of Military Ergonomics Division, USARIEM, to perform biophysical evaluations of military clothing for NATO and Commonwealth Defence Conference nations, we have responded favorably to a request from Australian government officials to measure the insulation and vapor transfer properties of Australian Army field uniforms using the copper manikin. Our aim was to demonstrate the important role of this device in assessing the protection capabilities of clothing systems, and for providing accurate data from which predictions of heat and cold tolerance could be made. In this way, we hoped to encourage other nations to acquire biophysical instrumentation and to use it as a first step in developing improved military clothing.

Progress:

Measurements of the Australian fatigue uniform, including add-on values for a sweater and field coat, and the changes in insulation and vapor transfer characteristics caused by the wearing of NBC protective items have been completed and the results provided to Australian officials. Insulation (clo) values and indices of evaporative cooling (i_m) are tabulated below.

Clothing Ensemble	clo	i_m	i_m/clo
Fatigue uniform[1]	1.50	0.45	0.30
plus sweater, pullover	1.94	0.36	0.19
plus field coat	1.77	0.36	0.20
plus sweater and field coat	1.99	0.32	0.16
Fatigue uniform, UK MK3 NBC suit, US M17A1 mask and M6A2 hood	2.32	0.31	0.13
Fatigue uniform, sweater, field coat, UK MK3 NBC suit, US M17A1 mask and M6A2 hood.	3.00	0.25	0.08

1. Fatigue uniform consisted of cotton T-shirt and shorts, fatigue shirt and trousers, wool socks, black boots and hat.

The values for the fatigue uniform with and without NBC items were similar to those obtained using US fatigue uniform items. The add-on values for the sweater (0.44 clo and -0.09 i_m) were not unusual in view of the thickness of the Australian sweater. This item, used with a field coat, is intended for protection during relatively cool exposures (10° C) and appears to be a worthwhile item of issue for supplementing the protection of the field coat.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Russian Polar Clothing (ME-E10-79)
Investigators:	Clement A. Levell and John R. Breckenridge

Background:

The Clothing, Equipment and Materials Engineering Laboratory (CEMEL) of NLABS has obtained through private channels a Soviet cold weather clothing ensemble worn at Vostok Station, Antarctica. This clothing was thick and obviously provided high insulation value and, in addition, had certain design features which were different from those found in conventional cold weather clothing. Especially noteworthy were a fleece-lined vest and fur-lined boots. At CEMEL's request, this ensemble was evaluated on the copper manikin to determine its heat and vapor transfer properties, in line with the USARIEM policy of examining foreign items to discover new features and ways of improving thermal protection of clothing.

Progress:

Insulation (clo) value and moisture permeability index (i_m) of the Soviet clothing have been measured on the non-sectional copper manikin. Results were as follows:

	clo	i_m	i_m/clo
Used Soviet polar ensemble*	5.01	0.42	0.08

*Russian items included lined trousers and parka with hood, fleece-lined vest, fur boots without inserts and lined gloves. The ensemble was completed with US military 50% wool/50% cotton winter underwear, and a pile-lined cap.

The insulation provided by this ensemble (5.01 clo) was the highest we have measured on a cold weather ensemble, and was 0.7 clo higher than for the US standard cold-dry uniform (4.3 clo). This level of protection is accomplished solely by using thick layers, but this thickness did not apparently reduce the vapor transport capabilities of the system since the i_m value was 0.42, which was about 5% higher than measured for most thick systems, and about as good as that found in lightweight clothing. Because of the high insulation value, the coefficient for evaporative heat transfer, i_m/clo is low (but no worse than for other cold weather systems) and little cooling by sweat evaporation can occur with the ensemble closed. However, it appears that overheating during exercise can be avoided by opening the parka and allowing the fleece vest to provide windchill protection for the chest and abdomen areas. This procedure would greatly reduce the clo value and increase the i_m/clo ratio (and evaporative cooling) proportionately.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Commercial Parkas with Thinsulate Insulation (ME-E14-79)
Investigators:	Clement A. Levell and John R. Breckenridge

Background:

A recent development by Minnesota Mining & Manufacturing Co. (3M) of an insulating material called Thinsulate has aroused considerable interest among clothing developers in view of its reported superior insulating characteristics. The 3M Company reported that their measurements indicated that this fine-fiber family of materials provided up to 30% more insulation per unit thickness than other available insulations, including down. USARIEM has conducted limited measurements on Thinsulate and clothing items employing this fine-fiber material and has not to date been able to demonstrate the superiority of Thinsulate as an insulating material. Despite these negative indications, Clothing, Equipment and Materials Engineering Laboratory (CEMEL), NLABS has continued its investigation of Thinsulate and has requested copper manikin evaluation of two commercial cold weather jackets with Thinsulate liners. This work is intended as merely a first step in an investigation to determine whether the current 4 oz polyester liners in cold weather clothing should be replaced with Thinsulate; later studies would be conducted to show the effect on insulating value of replacing the polyester liners with Thinsulate.

Progress:

The two commercial Thinsulate-lined jackets provided by CEMEL have been measured before and after laundering on the nonsectional copper manikin. In addition to one of the jackets, the manikin was dressed in a minimal insulation ensemble consisting of fatigue trousers, baseball cap, socks and combat boots to maximize the likelihood that effects of laundering, if any, would be demonstrated. The evaluations included measurement of the evaporative heat transfer characteristics (i_m) of the clothing systems. The results obtained were as follows:

Basic Ensemble plus	Unlaundered Jacket clo	Unlaundered Jacket i_m	Unlaundered Jacket i_m/clo	Laundered Jacket clo	Laundered Jacket i_m	Laundered Jacket i_m/clo
AMF Head Co. jacket	1.83	0.44	0.24	1.73	0.42	0.24
Sierra Designs parka with hood	2.09	0.39	0.19	1.98	0.40	0.20

A report to CEMEL pointed out that no comparison of insulation effectiveness of the Thinsulate liner material relative to that of polyester was possible from these limited data and recommended direct comparison of systems with the two types of liner material. The evaporative transfer characteristics of the Thinsulate appeared to be about the same as for other insulating materials; a 0.40 to 0.42 i_m value has been typical of a material with good vapor transfer characteristics. Based on USARIEM recommendations, CEMEL has initiated and funded an in-depth study of Thinsulate liners vs other liner constructions, which will be performed on the USARIEM sectional copper manikin to permit assessment of jacket characteristics alone.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Assessment of Finnish Paper Blankets (ME-E1-80)
Investigators:	John R. Breckenridge and John L. Fiumara

Background:

The US Army Medical Intelligence and Information Agency has requested a detailed examination and tests of three hospital paper blankets and one casualty evacuation paper blanket manufactured in Finland and acquired through the US Defense Attache in Finland. The purpose of these tests was to determine whether the blankets would be worth considering for procurement as medical items in the US military supply system. Information was requested on such aspects as quality, design features, utilization potential and costs, relative to any similar items currently in the US medical equipment inventory.

Progress:

Insulation values of samples cut from each of the paper blankets have been measured on an electrically heated guard ring flat plate. The three hospital blankets measured 1.39 clo, 1.65 clo, and 1.89 clo, respectively; and the casualty evacuation blanket measured 1.19 clo. These blankets would all provide more patient warmth and protection than one medium-weight Army wool blanket, which measures 1.17 clo; since all these values included 0.4 clo of insulation attributable to the air layer on the outer blanket surface, the paper blanket with 1.89 clo would provide about the same insulation as two wool blankets.

The blanket constructions have been examined to assess quality, durability, etc. All are constructed of smooth, moderately absorbent surface layers with multiple layers of crepe-style paper sandwiched in between. Investigations are continuing to locate similar items in the US military supply system.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Two Parkas for Antarctic Research Program (ME-E2-80)
Investigators:	Clement A. Levell and John R. Breckenridge

Background:

The National Science Foundation contractor responsible for procurement of clothing and equipment for the US Antarctic Research Program requested copper manikin evaluations of the protective properties of two commercial parkas to provide a basis for selection of the most effective item for procurement and shipment to Antarctica. The relative merits of the two parkas were determined by comparing insulation values and evaporative heat transfer potential (moisture permeability index) of a basic cold weather ensemble plus each of the parkas in turn.

Progress:

Evaluations of the two parkas were completed and results reported to the NSF contractor (Holmes & Narver, Inc) in time to allow NSF to meet their 3 December deadline for item procurement and delivery to the Antarctica supply ship. The parka being considered for procurement by NSF provided better insulation in the test ensemble (system insulation value of 4.34 clo) and higher moisture permeability index (0.39) than the parka used the previous year (system insulation of 4.12 clo and permeability index of 0.35). Total ensemble weight with the proposed parka, a down-filled item, was 20.1 lbs, compared to a weight with the 1979 parka, insulated with hollow fiber polyester, of 19.1 lbs. Based on these data, and a $50 lower unit cost, the former was considered more desirable by NSF than the 1979 parka and procured for the 1980 program.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, F. ꞁICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Aircrew NBC Protective Systems (ME-E3-80)
Investigators:	Ralph F. Goldman, Ph.D. and Clement A. Levell

Background:

Helicopter pilots flying in hot environments are frequently subjected to high levels of heat stress, due to the heating effect of solar radiation on the aircraft. Cockpit ventilation with ambient air is beneficial for holding the temperature and humidity in the aircraft at tolerable levels; however, missions in excess of two hours can produce extreme pilot fatigue and reduced effectiveness. We have studied the problem in the AH-IG Cobra helicopter (1) and made recommendations which led to the installation of air conditioning in this aircraft. However, this solution to the problem is not feasible in larger aircraft owing to the added power demand to operate an air conditioning system.

An urgent need to explore ways of alleviating the heat stress problem exists, especially since pilots in combat will most likely be wearing body armor and for over-water flight, survival vests: both will seriously reduce the cooling a pilot can obtain from sweat evaporation. Wearing chemical protective clothing in anticipation of NBC attack will further compound the problem. Accordingly, the USA Aeromedical Research Laboratory, FT Rucker, AL has requested USARIEM collaboration in studies of ways to alleviate cockpit heat stress. Possible approaches include use of a UK ventilated aircrew gas mask, with cockpit air both cooled and uncooled, and an ice vest, which has proven beneficial in the South African gold mines. This work will involve laboratory evaluations using the copper manikin, stress prediction modeling, and finally, flight testing of promising systems.

Progress:

In the first phase of this collaborative program, copper manikin measurements were made of insulation (clo) and moisture permeability index (i_m) of standard flight clothing plus three types of CW protection, namely, US liners (impregnated fatigues, worn under the Nomex flight suit), US charcoal-foam overgarment, and a UK CW undergarment. Results of these determinations are summarized in Table 1 below.

TABLE 1

Heat Transfer Parameters with Various Types of CW Protection

	clo	i_m	i_m/clo
Flight clothing* plus US CW hood, mask, gloves with:			
US impregnated liners	2.01	.29	.14
US charcoal-foam overgarment	2.57	.29	.11
UK undergarment	2.08	.32	.15

*Flight clothing consisted of Aviator's two-piece Nomex flight suit, Aviator's Helmet, cushion sole socks and combat boots.

These results indicate that the UK undergarment would be least stressful since its i_m/clo ratio, which is a measure of evaporative cooling potential, is higher than for the other two systems.

A preliminary study was also made of the UK ventilated gas mask, with the blower circulating ambient, 27°C air over the face of the manikin or with the blower shut off. This study was conducted with the manikin dressed in a complete system including one-piece flight coverall, survival vest, and armored vest with front and back plates. Results of the measurements are given in Table 2.

TABLE 2

Effects of Ventilating the UK Mask with Ambient Air

(Manikin dressed in flight clothing, US CW hood, mask, gloves and UK CW overgarment)

	clo*	i_m*	i_m/clo*
Blower off	2.20	.29	.13
Blower on	1.83	.33	.18

*Values are for entire manikin, not just the head.

With the "skin" on the manikin head wet, evaporative cooling with the blower on was increased (according to i_m/clo ratios) by 38% (.05/.13). Insulation value (clo) was reduced, but the reduction from 2.20 clo to 1.83 clo would have had little effect in reducing stress since cockpit air and skin temperatures would not have differed greatly.

LITERATURE CITED

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of 20 Cold Weather Underwear Fabrics (ME-E4-80)
Investigators:	John R. Breckenridge and John L. Fiumara

Background:

Clothing, Equipment, and Mechanical Engineering Laboratory (CEMEL) of NLABS is in the process of selecting an improved underwear fabric to replace the 50% cotton, 50% wool material currently being specified for cold weather underwear. To guide them in their selection, CEMEL requested a biophysical evaluation of 20 candidate materials on our heated, "sweating" guard ring flat plate. This device measures thermal insulation (clo value) and, when wetted, the moisture permeability index, i_m. This index is directly related to the evaporative heat dissipation from a totally wet surface, and is indicative of the ease with which sweat can be evaporated through a fabric system.

Progress:

Ten of the candidate materials plus the standard 50% cotton, 50% wool rib knit used in current issue cold weather US Army underwear have been measured on the flat plate. Results of these determinations are given in Table 1.

TABLE 1

Insulation (clo) and Moisture Permeability Index (i_m)
Values for Underwear Fabrics

Description	clo	i_m	i_m/clo
50%cotton/50%wool knit (US Army standard fabric)	0.77	0.59	0.77
Double layer fabric: outer layer 65% cotton/25%wool/10%nylon; inner layer 100% cotton	0.75	0.57	0.76
Double layer fabric: outer layer 50% cotton/40%wool/10%nylon; inner layer 100% cotton	0.76	0.65	0.86
Double layer fabric: outer layer 50% polyester/50%acrylic; inner layer 50% cotton/50%acrylic	0.74	0.59	0.80
100% Nomex double layer bi-ply fabric	0.77	0.64	0.83
100% Nomex double layer twin-knit fabric	0.78	0.59	0.76
85% Vinyon/15% acrylic interlock knit fabric	0.78	0.64	0.82
Two-fabric combination: inner fabric: cotton ladder weave brynje; outer fabric: sample #1	1.24	0.63	0.51
80% PFR rayon/20% Nomex fabric	0.82	0.62	0.76
85% merino wool/15% nylon rib knit	0.78	0.62	0.79
Sample #10 stretched approx. 20%	0.78	0.62	0.79

The insulation values of the samples were all about the same except for the two-fabric combination, which was thicker. The permeability index (i_m) range was also narrow, from 0.57 to 0.65. These high values are typical of fabrics which offer little or no resistance to evaporative transfer.

In view of the similarity of clo and i_m values for all the single layer fabrics, irrespective of fabric weave or fabric type, the Project Officer, CEMEL decided that further evaluations would be uninformative. Accordingly, the decision was made not to measure the additional 10 fabrics, as had originally been planned.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Gore-tex Clothing Systems (ME-E5 -80)
Investigators:	John R. Breckenridge and Clement A. Levell

Background:

The recently introduced "one-way permeable" film trademarked Gore-tex is finding increasingly greater application in civilian wet-weather gear. Laminates of this film with various fabrics are waterproof, but reportedly offer little resistance to the passage of water vapor. If this is true, an ensemble can be made rainproof (by using a Gore-tex outer layer) without interferring appreciably with sweat evaporation or the dissipation of water vapor through the clothing. Such laminates might also be used on the inside of cold weather ensembles to prevent excess sweat from being blotted into the clothing layers and reducing their insulating effectiveness. Various laminates are being studied by Army clothing designers to determine their suitability for military clothing and equipment applications.

In line with the mission to define and characterize heat exchanges between clothed man and his environment, several new concept items of cold weather clothing from Synergy Works of California were studied. These items included a cold weather parka with Gore-tex shell, a vapor-barrier shirt to prevent sweat uptake by the clothing, and a Fiberpile sweater. Both the sweater and parka feature zippered ventilation closures under the arms. These items were studied alone and in combination on a copper manikin to determine their insulating and evaporative transfer characteristics.

Progress:

Results of the static manikin measurements on the new concept items are summarized in Table 1.

TABLE 1

Insulation (clo) and Moisture Permeability Index (i_m)
Values for Clothing with New Concept Items

	clo	i_m	i_m/clo
Basic system*	1.31	0.40	0.31
plus			
Vapor barrier shirt	1.51	0.28	0.19
Fiberpile sweater (vents closed)	1.84	0.43	0.23
Gore-tex parka	1.67	0.34	0.20
Fiberpile sweater plus Gore-tex parka	2.16	0.37	0.17
Vapor barrier shirt, Fiberpile sweater, Gore-tex parka	2.16	0.23	0.11

*Basic system consisted of combat fatigue trousers, long-sleeved cotton shirt, baseball cap, socks and combat boots.

These values indicate that the vapor barrier shirt was misnamed, since it provided only marginal resistance to vapor transfer (reduction in i_m from 0.40 to 0.28 when added to basic system). The fiberpile sweater added about 0.5 clo of insulation without reducing i_m. The Gore-tex parka, a windbreak type, added some insulation and did not greatly reduce vapor transfer, considering that it is a waterproof item. This parka was, however, partly responsible for the low i_m value when all three new concept items were combined; the vapor barrier shirt added the remainder of the resistance to produce the low i_m value of 0.23.

No evaluation of the ventilation features of the sweater and parka was made for lack of an articulated manikin. These items will, however, be informally evaluated for comfort and protection during the coming winter.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of USAF Containerized (vacuum packed) Sleeping Bag (ME-E6-80)
Investigators:	Clement A. Levell and John R. Breckenridge

Background:

The US Air Force has a requirement for a containerized, vacuum packed sleeping bag which could be carried as survival gear in aircraft operating over Arctic and sub-Arctic land masses. Arrangements were made with USARIEM to evaluate a prototype item under our Memorandum of Agreement with the Air Force. This study involved measurement, on a heated copper manikin, of its insulation value before vacuum packing and after removal from vacuum packaging. As a sub-study, arrangements were also made to measure other bags which the Air Force felt might be candidates, namely a bag with a Gore-tex shell (to provide waterproofing) and one containing reflective layers (1), which were employed to reduce radiant losses through the insulation.

Progress:

Insulation values of the prototype containerized bag before and after vacuum packing, plus values on the Gore-tex covered and reflective layer sleeping bags were measured on a supine copper manikin. Results of the evaluations are given in Table 1, along with values for a standard US Army LINCLOE type bag used at USARIEM as a control.

TABLE 1

Insulating Values of Sleeping Bags

	Insulation Value (clo)	Weight (lbs)
Control (standard) LINCLOE bag	6.79	9.8
North Face Superlight (before vacuum packing)	5.66	3.6
North Face Superlight (after vacuum packing)	4.77	3.6
Gore-tex covered bag	6.45	3.8
Gore-tex covered bag with reflective liner, reflective side in	6.83	4.2
Gore-tex covered bag with reflective liner, reflective side exposed	6.98	4.2

The candidate bag for vacuum packing did poorly, losing 0.89 clo, or 16% of its clo value after vacuum packing despite repeated attempts to refluff the down fill. Previous measurements of vacuum packed down bags from the same manufacturer, but with thicker insulation, (under studies in FY 79) showed very little degradation of insulating value following vacuum packing. With regard to the bags with reflective liners, insulation increases of 5% to 7% were noted; however, part of this may have resulted from adding the reflective liner to the system rather than from any effects on radiant heat exchange it might have had.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of NATO Combat Footwear (ME-E7-80)
Investigators:	John R. Breckenridge and Leander A. Stroschein

Background:

For the past 10 years, the USARIEM attendee at the NATO Combat Clothing and Equipment Working Party (CCEWP) meetings at Brussels and the Hague has encouraged the members to have their nations adopt a systematic approach to the evaluation of combat clothing, including biophysical measurements of heat transfer properties, predictions of heat and cold stress on the wearer in terms of activity level and environment, appropriately designed chamber studies and, finally, field evaluations. This effort has culminated in the preparation of a NATO Allied Publication "Heat Transfer and Physiological Evaluation of Clothing", which is awaiting Army Board approval. In line with this effort, it has been USARIEM policy to make biophysical measurements of clothing properties for NATO members of the CCEWP since, until recently, none has had the capability required for this phase of clothing evaluation. The present study continues this policy by making use of the USARIEM sectionalized copper foot for measuring sectional insulation values of combat boots submitted by CCEWP member nations,.

Progress:

Sectional insulating values of 11 sockgear/combat boot combinations submitted by CCEWP nations have been measured on a new, automatically controlled 26-section copper foot. While these measurements were accomplished rapidly without encountering any control or temperature measurement problems, these appears to be a problem correlating these results with those previously reported using the old apparatus. Transmission of results to NATO nations has been delayed pending further evaluation of the new sectional foot, and correlation of the results on this device with those obtained on an older model foot. The older foot was not representative of the shape of an actual foot and caused lower insulation values to be recorded for certain regions of boots being evaluated Results of the measurements on the NATO combat boots will accordingly not be reported until correction/calibration factors have been established for relating values measured on the old and new sectional feet.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Calibration Comparison of USARIEM and Commercial Flat Plate Results (ME-E8-80)
Investigators:	Ralph F. Goldman, Ph.D., John R. Breckenridge and John L. Fiumara

Background:

The guard ring flat plate has been used extensively for over 40 years to measure thermal insulation of fabrics and batting materials; standard procedures for these measurements have been specified by the American Society for Testing Materials (1). More recently, in the early 1960's, USARIEM developed a flat plate with the capability of maintaining a wetted surface, which permitted the water vapor transfer characteristics of insulating materials to be measured; this plate could also be run with a dry surface to measure thermal insulation. It was thus possible to quantify the two parameters which determine the rate of heat dissipation through a textile system, namely (1) the insulation (clo) value for describing non-evaporative, "dry" heat exchange and (2) the moisture permeability index of Woodcock (2) which, in combination with the clo value, describes the additional heat loss resulting from evaporation when the underlying heated surface is wet. This development had tremendous implications since the two-parameter concept could determine the heat dissipation range of a soldier in a given clothing system and environment, from the minimum when the skin is dry to a maximum when the skin is totally wet.

In the past few years, interest in the "sweating" flat plate has increased as the potential of the USARIEM system has become known. Several NATO nations have acquired or are in the process of developing similar instrumentation, and a few US companies dealing with fibers or textiles are proceeding to acquire this capability. USARIEM is interested in these developments and is encouraging information exchange on "sweating" flat plate results to insure consistency of results. Arrangements were made with E. I. Dupont de Nemours Corporation for parallel evaluations of three DuPont fabrics on the USARIEM and DuPont plates, in order to check the reproducibility of the system.

Progress:

The three DuPont fabrics have heen evaluated on the USARIEM flat plate. Insulation (clo) value for each fabric was measured four times, and moisture permeability index (i_m) three times per day for three days. The average insulation values and the daily/overall averages for the three fabrics are shown in Table I.

TABLE 1

Insulation (clo) and Evaporative Transfer Characteristics (i_m/clo) of DuPont Fabrics

Sample	clo		i_m	i_m/clo
4524-27B3	.69			
		day 1	.63	.91
		day 2	.61	.88
		day 3	.62	.89
		Avg.	.62	.89
4524-89D3	.70			
		day 1	.62	.86
		day 2	.61	.87
		day 3	.62	.86
		Avg.	.62	.86
4524-24B1	.66			
		day 1	.60	.91
		day 2	.61	.93
		day 3	.60	.91
		Avg.	.60	.92

While the daily averages of i_m for each fabric agree within 3%, no estimate of the reliability of these results can be made until measurements of the fabrics have been completed by DuPont. Their values are expected shortly.

LITERATURE CITED

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2. Woodcock, A.H. Moisture transfer in textile systems, Part I. Text. Res. J. 32: 628-633, 1962.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulating Values of USAF Women's Uniforms (ME-E9-80)
Investigators:	Clement A. Levell, John R. Breckenridge and Ralph F. Goldman, Ph.D.

Background:

The US Air Force, through its Clothing Division at Wright-Patterson Air Force Base, OH, has arranged with USARIEM for evaluation of the insulating effectiveness of the USAF Women's blue, 3356 raincoat, with and without its removable liner, when worn with various authorized women's uniform ensembles. This was to provide the data base for women's ensembles and to determine the adequacy of protection for personnel going outdoors in cold environments for short periods of time (15 to 30 minutes). The Clothing Division was also interested in comparing the insulating values of women's ensembles with similar purpose ensembles for men, to insure that females and males would be provided comparable protection during routine activities at Air Force cold climate installations (including short trips to the flight line when necessary). Accordingly, measurement of insulation values for a number of authorized men's garrison ensembles, plus selected flight clothing, was also included in the tasking document.

Progress:

Insulation measurements of 50 separate men's and women's ensembles were made using electrically heated copper manikins. A smaller model was used for the evaluation of women's ensembles, so as not to require oversize women's garments. Men's ensembles were measured on a larger manikin anthropometrically patterned after a "standard" Army soldier. Several men's ensembles were measured on both manikins to verify that the insulation values were not dependent on the manikins employed.

A partial listing of results for the women's ensembles is given in Table 1.

TABLE 1

Insulation Values of USAF Women's Ensembles

(clo units)

Ensemble*	under raincoat with liner	under raincoat without liner
Issue pants suit with tuck-in shirt	1.98	1.83
Issue pants suit with regular length overblouse	1.90	1.77
Issue pants suit with long length overblouse	1.95	1.78
Optional pants suit with tuck-in shirt	1.90	1.76
Optional pants suit with regular length overblouse	1.85	1.68
Optional pants suit with long length overblouse	1.85	1.68
Issue coat & skirt with tuck-in shirt	1.67	1.61
Issue coat & skirt with regular length overblouse	1.62	1.56
Issue coat & skirt with long length overblouse	1.62	1.56
Optional coat & skirt with tuck-in shirt	1.63	1.55
Optional coat & skirt with regular length overblouse	1.58	1.50
Optional coat & skirt with long length overblouse	1.58	--
	under overcoat with liner	under overcoat without liner
Issue pants suit with tuck-in shirt	1.82	1.77

*Ensemble included commercial undergarments, beret and black pumps.

Other comparisons using the "add-on" technique, i.e., measuring insulation with and without an item and determining its effect from the difference found, led to the following conclusions.

a. The issue sweater, worn as an outer garment, added from 0.11 to 0.14 clo of insulation value.

b. The issue sweater, worn under the lined raincoat, added only 0.01 clo of insulation (the sweater was simply substituted for the air space beneath the raincoat liner).

c. The raincoat with liner added from 0.36 to 0.40 clo of insulation.

d. Pantyhose had negligible effect on overall insulating value.

Results obtained for the men's ensembles are summarized in Table 2.

TABLE 2

Total Insulation Values of USAF Men's Ensembles

(clo units)

Ensemble*	Insulation Value
Issue suit, long sleeve shirt, raincoat with liner	2.11
Issue suit, long sleeve shirt, raincoat without liner	1.96
Issue suit, long sleeve shirt	1.64
Issue suit, short sleeve shirt	1.64
Jacket, lt. wt. with liner over long sleeve shirt & trousers	1.78
Jacket, lt. wt. without liner over long sleeve shirt & trousers	1.59

*including cotton briefs and undershirt, shoes, socks, and tie.

Ensemble**	Insulation Value
Coverall, flyer's - standard	1.81
Coverall, flyer's - Experimental #1, Interliner 200-2308-52D	2.44
Coverall, flyer's - Experimental #2, Insulate CS-150-8148-18A	2.39
Jacket & trousers, cold weather - standard	2.75
Jacket & trousers, cold weather - CS 200-8308-52D	2.55
Jacket & trousers, cold weather - CS 150-9148-18A	2.55

**Including cotton briefs, undershirt, shoes, socks.

The report to the Clothing Division provided general guide-lines for determining the minimal acceptable temperatures for comfort in the various men's and women's ensembles, assuming light to moderate activity level of the wearer. Information was also provided on the effect of increased activity level on the comfort temperature range (15 kcal/hr increase lowers the range 1° C), and on metabolic heat production rates for various types of office work.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Heated Liner System for Casualty Evacuation Bag (ME-E12-80)
Investigator:	George F. Fonseca, M.S.

Background:

This study was initiated at the request of the US Army Medical Bioengineering Research and Development Laboratory (USAMBRDL) to evaluate an Army Life Support Power Source System (ALPSS) and tubulated pad designed to supply heat to a casualty during holding or evacuation to the rear. This pad is placed under the patient, inside the casualty evacuation bag, and must supply sufficient heat in extreme cold to prevent chilling of the patient.

Progress:

This system was evaluated in the Arctic Wind Tunnel of the Climatic Chambers, NLABS by placing the sectional manikin inside the evacuation bag with the head pointing into the wind, lying on the liner pad, and measuring the heat loss in a minus 35° C environment air flow 1.1 m/s. The heat transferred from the manikin through the casualty evacuation bag and tubing liner combination to the air and the floor of the Arctic Wind Tunnel was 118 watts (102 kcal/hr) when the fluid in the liner tubing was not heated. When the fluid was heated and flowing the corresponding heat transfer from the manikin was 80 watts (69 kcal/hr), not a very impressive reduction in heat loss and not enough to suggest that this version of auxiliary heating to protect a casualty is even worth testing. The heated fluid flowing through the tubing of the liner decreased the manikin heat loss by only about 32%. A technical letter report was written, completing this study.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Performance Characteristics of New Sectional Copper Foot (ME-E13-80)
Investigators:	Leander A. Stroschein, Clement A. Levell and John R. Breckenridge

Background:

Electrically heated biophysical devices such as the copper hand, copper foot, and copper manikin provide a means for making rapid, accurate measurements of clothing thermal insulation. Results obtained on these devices are useful for comparing the thermal protection provided by experimental uniforms or extremity items, and are entirely satisfactory for predicting skin-to-air heat losses for resting men. These devices have been regularly used in this Institute since its organization in 1961, and at its parent organizations since 1948. A sectionalized copper foot was procured in the early 1960's to allow study of the distribution of insulation over the foot with various types of footwear. Results have been used to assess the merits of prototype military items; to make design adjustments during footwear development programs; and to provide general guidance to footwear designers which has enabled them to adjust insulation thickness over various regions of the foot for optimal protection. This first sectionalized copper foot had 12 separate measuring sections; their temperatures were set by manual adjustments of power to the 12 heaters, which was a tedious process. Each evaluation required a minimum of two days.

Recently Institute personnel designed two new copper feet, incorporating 27 separate measuring sections, which provides a vastly improved temperature measurement and control capability. An automatically-adjusted power supply system, driven by a programmable calculator, adjusts the temperature levels of the sections. The feet are more representative of the human foot than the old model, which was simply the copper sections fastened to a boot last.

The present study was introduced to develop software for optimal temperature control of the new feet, to study their operating characteristics, and to make comparisons with the old feet.

Progress:

Programming for reading foot section temperatures and converting these data into power adjustment instructions for the controller has been developed and tested. In general, all foot sections can be brought to within $\pm$ 0.1^{o} C of a selected set point within one hour, and a satisfactory equilibrium for insulation measurements attained within four hours with thick footwear. Studies have shown that the orientation of the foot with respect to the air motion in the environmental chamber affects the surface air film pattern over the foot, and hence the distribution of boundary air layer insulation. This boundary air layer insulation adds to the intrinsic insulation value of the footwear in determining total insulation over each copper foot section. A standard placement of the foot in the chamber has therefore been specified to permit valid comparison of footwear tests.

Studies have shown that the new feet indicate higher sectional insulation values for certain zones of a footwear item than were measured on the old feet. These differences arise because the old feet, made from a shoe last, fit the boot more snugly than the new feet. Air trapped between the last and the footwear provides little thermal insulation, but can be an important factor with the new feet, which have realistic, life-size shapes. The differences are especially apparent in the instep and toe regions, and amount to as much as 0.3 clo, depending on the shape of the footwear.

The new copper feet have been operated without difficulty during the first study: the measurement of NATO nations combat boots, which is reported elsewhere.

Deliberations are currently underway to determine how best to resolve the effects of differences between the old and new feet in reporting sectional insulating values to footwear designers. One approach being considered is remeasurement of all standard military footwear items on the new feet to provide a new data base.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Temperate Battle Dress Uniform (ME-E14-80)
Investigators:	Clement A. Levell and John R. Breckenridge

Background:

The Clothing, Equipment and Materials Engineering Laboratory (CEMEL) of NLABS is in the process of standardizing a new temperate and tropical battle dress uniform with disruptive camouflage pattern. This camouflage pattern is similar, but not identical, to that used on the current standard tropical uniform. The question has arisen whether the dyes and dyeing processes used in making the fabrics for the new uniform would have any adverse effect on its evaporative heat transfer properties. A request was made to make copper manikin measurements of the insulative (clo) and vapor transmission (moisture permeability index, i_m) properties of the two uniforms to reveal any differences due to fabric construction and dye process.

Progress:

Copper manikin biophysical measurements on the two uniforms have been completed. Both uniforms had almost the same insulating (clo) values: 1.44 clo for the standard uniform and 1.45 clo for the proposed uniform. More importantly, both had identical permeability index values of 0.42. CEMEL was accordingly advised that it was reasonable to expect that there would be no subjective or objective differences in the relative comfort, discomfort, or heat tolerance of men wearing these two uniforms.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulation of Air Force Flight Clothing Ensembles (ME-E15-80)
Investigators:	Thomas L. Endrusick and Clement A. Levell

Background:

Aeronautical Systems Division, Department of the Air Force requested copper manikin measurements of eight possible cockpit clothing ensembles to establish effects of compression (loss of insulating value), to verify computer profiles being developed by USAF School of Aerospace Medicine, and to indicate areas of heat/cold stress under various cockpit conditions. A 15-section seated sectional manikin obtained from the Air Force several years ago under a Memorandum of Agreement was to be employed for these measurements, to provide detailed information on the distribution of insulation over the body with the various ensembles. Work was performed under a Military Interdepartmental Purchase Request.

Progress:

Measurements of the Air Force flight ensembles has recently commenced, following a training period on operation of this copper manikin for technical personnel and corrections of several measuring circuit malfunctions. Results obtained to date are tentative requiring verification and analysis. Complete information on these ensembles will be provided at a future date.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Chemical Heating Pack (Hot Mini 24) (ME-E17-80)
Investigators:	John R. Breckenridge and John L. Fiumara

Background:

Headquarters, US Army Medical Research and Development Command requested evaluation of a chemical hand warmer obtained from Triangle Manufacturing Inc., Raleigh, NC. to determine its merits as a possible medical supply item. Claims by the distributor of this small pouch were that it would maintain a temperature of 120° F for 24 hours, and warm hands when operating equipment without gloves. It was described as an "ideal survival item". A similar heating pad was evaluated by USARIEM for its heat production capabilities in 1978; that pad produced 3.1 watts maximum, which was not considered sufficient to maintain manual dexterity for a relatively inactive man in ambient temperatures below -25° C, even with the hand in an Arctic mitten. Goldman (1) has shown, however, that 3 watts is sufficient to protect the hand indefinitely at this temperature; maintaining a 40° F skin temperature, but that 5 watts is needed to hold the hand at 60°F, which is required to maintain manual dexterity.

Progress:

As in the earlier study, the heat produced by the Hot Mini 24 heating pad was determined by placing it on a heated flat plate, and measuring the losses from the plate to a cold environment before and after the chemicals in the pad were activated (by opening air vents on its surfaces). The reduction in heat loss to the environment with the pad activated was a direct measure of the heat it produced, inasmuch as the plate and pad were covered by an insulating layer

± 100% efficient for the heat given off by the pad. Repeated measurements on two different pad samples indicated that their heat production rate did not exceed 1.9 watts despite careful attempts to insure thorough mixing of the chemicals. With the plate operated at 33° C in a 4° C environment, the temperatures attained on the surface of the pads did not exceed 31° C. On the basis of these findings, it was concluded that this particular pad type produced too little heat to warrant consideration as an item for protecting the extremities in cold environments.

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(126)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OA 6148	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NC	☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A879	BC	126
b. FORMER	6.27.77.A	3E162777A845	00	051
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code) (U)Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS
012600 Pharmacology; 005900 Environmental Biology; 013400 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	7.0	394
	CURRENT 81	9.0	244

19. RESPONSIBLE DOD ORGANIZATION
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RESPONSIBLE INDIVIDUAL
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20. PERFORMING ORGANIZATION
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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
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TELEPHONE: 955-2893
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: YOUNG, Andrew J., Ph.D., CPT, MSC
NAME: CYMERMAN, Allen, Ph.D.
NAME: MAHER, John T., Ph.D. DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Acute Mountain Sickness; (U)Altitude Acclimatization; (U)Hypoxia; (U)Pulmonary Edema; (U)Load Carriage; (U)Endurance Capacity

23. TECHNICAL OBJECTIVE. 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Exposure of soldiers to high terrestrial elevations results frequently in reduced military performance as well as medical disabilities which are incompatible with the successful completion of military operations. The purpose of this work unit is to characterize these performance decrements and disabilities and to investigate the basis of and methods for their prevention and treatment.

24. (U) Studies will be conducted in man to (1) determine the mechanisms of the physiologic alterations and medical disabilities at altitude; (2) assess and predict the performance of individuals and small units operating at altitude; (3) evaluate the efficacy of pharmacological agents and other means in preventing or reducing performance decrements and illness; (4) enhance the rate of adaptation to high terrestrial elevations.

25. (U) 79 10 - 80 09 (1) Contrary to expectation, soldiers suffering moderate to severe acute mountain sickness at 4,300 meters did not exhibit lower ventilatory rates than their less sick counterparts either before, during or after fatiguing isometric exercise; (2) Maximum isometric handgrip strength increased 11-16% while endurance time to complete handgrip fatigue decreased 9-22% in soldiers residing at 4,300 meters for 6 days; (3) the anticonvulsant drug phenytoin (Dilantin®), 300 mg/day, showed no effect on ventilatory rate or alveolar gas tensions at sea level and at 4,575 meters simulated altitude; (4) Soldiers carrying 30 kg loads for 4.8 km at high altitude voluntarily paced themselves at a walk rate which produced 50% of their maximal oxygen uptake; (5) Studies were carried out to examine the influence of 20 days' residence at 4,300 meters on the relationship between submaximal endurance capacity and the rate of muscle glycogen utilization.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Ventilation During Isometric Exercise at High Altitude
Investigators:	Richard L. Burse, Sc.D., Allen Cymerman, Ph.D., Andrew J. Young CPT, MSC, Ph.D., James E. Wright, CPT, MSC, Ph.D. and John T. Maher, Ph.D.

Background:

The severity of acute mountain sickness (AMS) symptomatology has been reported to be inversely related to the extent of the ventilatory response to high-altitude hypoxia (1,2): the greater the increase in ventilation, the less the severity. Neither individual susceptibility to AMS nor the ventilatory response to altitude exposure can be predicted prior to hypoxic exposure, either to altitude or to hypoxic gas mixtures in the laboratory. A simple predictive test to be given prior to ascent that may estimate an individual's ventilatory response to altitude hypoxia and possibly his susceptibility to AMS would be of great military value.

The purpose of this study is to evaluate the utility of an exercise task done at sea level as a predictor of both ventilatory response and relative susceptibility to AMS upon exposure to high altitude. The task is isometric exercise done to fatigue, which induces a marked hyperventilatory response in some individuals at sea level (3,4). Whether those individuals showing this response (responders) are the same individuals who also show marked hyperventilation upon altitude exposure, with reduced severity of AMS symptoms, is not known and is to be investigated.

In this study the ventilatory response during fatiguing isometric handgrip exercise (5) at sea level was compared to the initial and subsequent ventilatory response to altitude exposure at 4300 meters at the summit of Pikes Peak. Responses were associated with the severity of AMS symptomatology as assessed by the Environmental Symptoms Questionnaire (ESQ,6). It is hypothesized that individuals who exhibit a marked hyperventilatory response to fatiguing isometric exercise at sea level (responders) will also show a greater hyperventilatory response at altitude, both at rest and during isometric exercise. Responders should also manifest AMS symptoms of less severity than non-responders.

The military relevance is to determine if soldiers who are relatively susceptible (or resistant) to AMS can be identified by this simple exercise task done at sea level, prior to their actually being exposed to hypoxic conditions. If this is possible, then such a test might be used in pre-selection of resistant individuals for mountain training, or for medical monitoring of susceptible individuals after rapid translocation to altitude. In addition, mass screening of troops at sea level might serve to predict the approximate number of AMS casualties, by severity, which medical channels could expect to treat/evacuate during large-scale unit operations.

Progress:

The maximum handgrip strength (MHS) and the endurance and ventilatory responses to four trials of isometric handgrip exercise separated by 11-15 minutes were determined on five separate days at sea level in 14 male volunteer soldiers. Subsequently, one soldier was medically excluded from participation at altitude. Of the remaining 13 soldiers who were retested at 4300 meters altitude, the results from one were excluded because of serious doubt about the veracity of his ESQ symptom ratings. Another soldier voluntarily withdrew at the end of day 2 at altitude.

By day 2, 6 subjects had indicated one or more symptoms on the ESQ by which they clearly could be judged to have been suffering from moderate to severe AMS; these subjects formed the SICK group. Of the remaining 6 subjects, 4 indicated no AMS symptoms other than slight to moderate headache and 2 had symptoms indicative of only mild AMS; these formed the "not very sick" or WELL group. By day 6 at altitude, the SICK group size was reduced to 5 (all but 1 of whom were nearly well) by the withdrawal of one subject during the evening of day 2. The WELL group remained intact and was essentially asymptomatic. The symptomatology for each subject during the first 2 days at altitude is shown in Table 1.

TABLE 1

PEAK AMS SYMPTOMATOLOGY ON DAYS 1 AND 2 OF EXPOSURE TO 4300 METERS ALTITUDE BY CLASSIFICATION INTO SICK AND WELL GROUPS

	SICK GROUP						WELL GROUP					
SYMPTOM / Subject Number	1	2	3	4	5	6	7	8	9	10	11	12
Headache	4	5	1	4	5	4	1	0	1	1	0	0
Head throbbing	4	5	0	4	5	4	2	0	1	0	0	0
Light-headed	3	3	2	3	5	2	2	1	1	0	0	0
Faint	1	3	2	2	1	2	2	0	0	0	0	0
Hard breathing	2	3	3	1	0	0	0	1	0	0	0	3
Nausea	2	3	5	1	5	1	0	0	1	0	0	0
Upset stomach	3	3	5	1	5	1	0	0	1	0	0	0
Weakness	2	3	4	1	3	2	2	1	1	0	0	1
Vertigo	1	2	3	1	3	2	2	0	0	0	0	0
Tired	1	3	5	1	4	3	2	0	0	0	0	0
Isomnia	4	5	5	3	5	4	0	1	0	0	2	0

0 = none, 1 = slight, 2 = somewhat, 3 = moderate, 4 = severe, 5 = very severe

Peak minute ventilatory rates during the 4 endurance handgrips or in the first minute of recovery are shown in Figure 1. The peak ventilatory rates were similar for all 4 handgrips in both the SICK and WELL groups. The groups had almost identical mean values at sea level (range 28-40 $l \cdot min^{-1}$), on day 2 at altitude (range 35-46) and for grips 2-4 on day 6 at altitude (range 45-55), with the maximum difference being only 8 $l \cdot min^{-1}$. Peak rate during grip 1 on day 6 at altitude was 13 $l \cdot min^{-1}$ (or 26%) higher in the SICK than in the WELL group, but this difference disappeared in the second through fourth grips. It is clear that the peak ventilation on day 2 at altitude was increased above that at sea level. The overall average was increased 17% in the SICK group and 19% in the WELL group. There was an even greater increase in peak ventilation from day 2 to day 6 at altitude; 23% in the SICK group and 24% in the WELL group. Clearly, both groups responded to altitude in an identical manner and the hypothesis of being able to discriminate between them by their peak ventilatory responses to fatiguing exercise must be rejected.

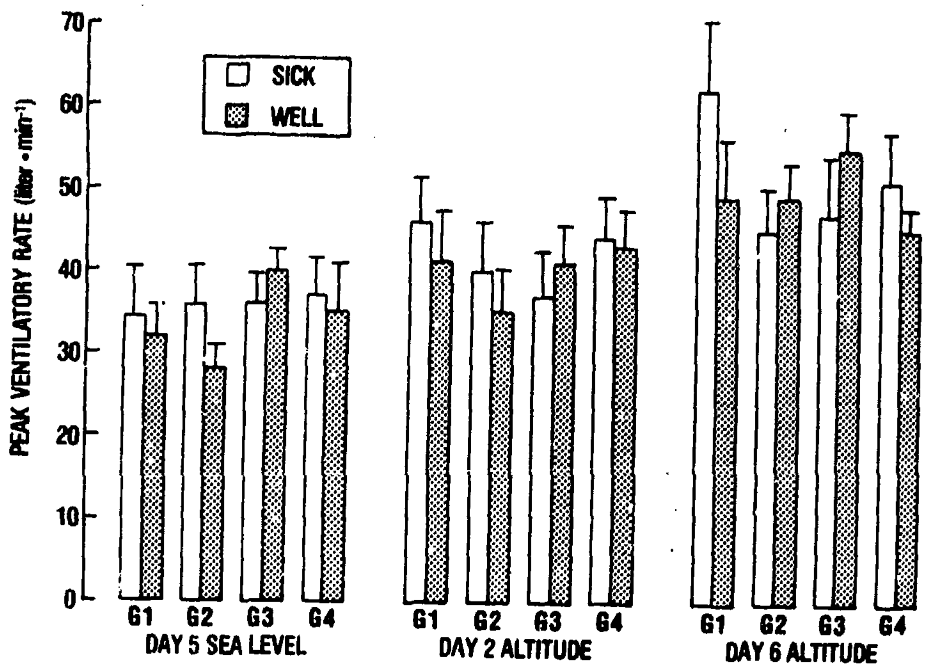

Figure 1. Peak ventilatory rates for isometric handgrips 1-4 (G1-G4) at sea level and after 2 and 6 days at 4300 meters altitude. SICK group = those suffering moderate to severe AMS; WELL group = those suffering no to slight AMS.

Despite the lack of differences between the SICK and WELL groups in their peak ventilatory responses, the overall pattern of response before, during or after the handgrip exercise might have differed. Therefore individual ventilatory rates were plotted, Figures 2 and 3 show the ventilatory rates at sea level before, during and after grips number 1 and 4, respectively. From these figures, which are also representative of the responses during grips 2 and 3 (not shown), it is clear that the SICK and WELL subjects did not differ at all in either magnitude or pattern of their ventilatory responses at sea level. Thus one is forced to conclude that the ventilatory response to handgrip exercise at sea level is not a predictor of susceptibility to AMS upon later exposure to high altitude.

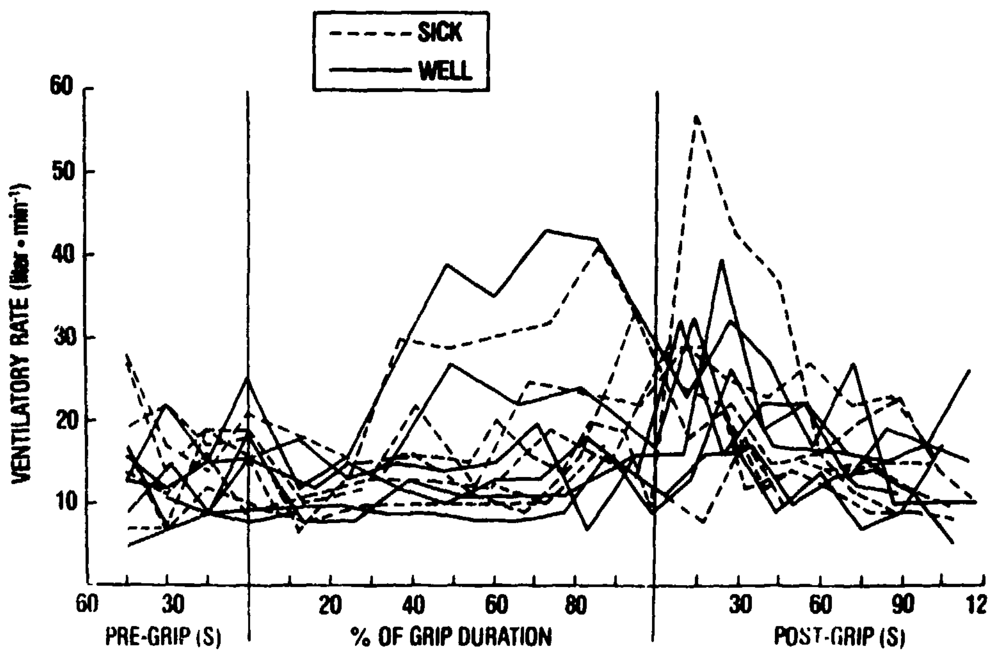

Figure 2. Ventilatory rates for each subject before, during and after the first of four fatiguing isometric handgrip contractions at 40% MHS: sea-level values.

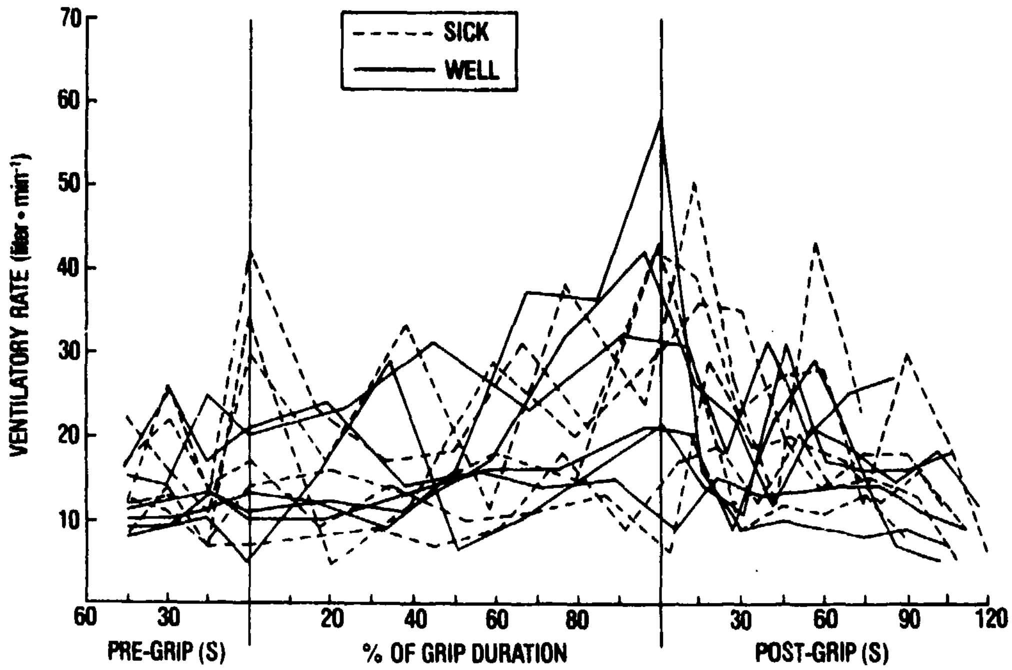

Figure 3. Ventilatory rates for each subject before, during and after the last of four isometric handgrip contractions at 40% MHS: sea-level values.

Similarly, Figures 4 and 5 show the individual ventilatory rates throughout handgrips 1 and 4 on the second day at altitude for the SICK and WELL grips. Again, there are no differences in magnitude or pattern of the ventilatory responses of the two groups. The resting ventilations prior to grip 1 are the same, indicating that resting ventilation at altitude was not related to presence or absence of moderate to severe AMS in this sample of soldiers. Comparison of the results at sea level (Figures 2 and 3) and after 2 days at altitude (Figures 4 and 5) confirms the increases in resting ventilation at altitude observed in a number of prior studies. Such increases in resting ventilation are maintained throughout and after the handgrip exercise, indicating that the altitude-stimulated increases and the exercise-stimulated increases are not mediated by the same mechanism, but are additive in their effects.

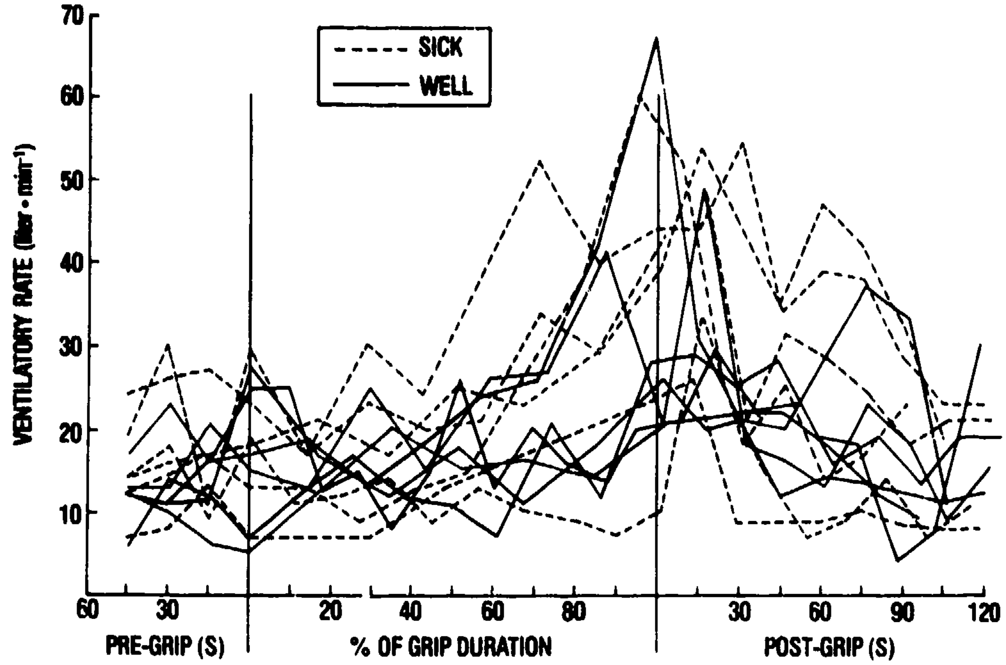

Figure 4. Ventilatory rates for each subject before, during and after the first of four isometric handgrip contractions at 40% MHS: values after 2 days residence at 4300 meters.

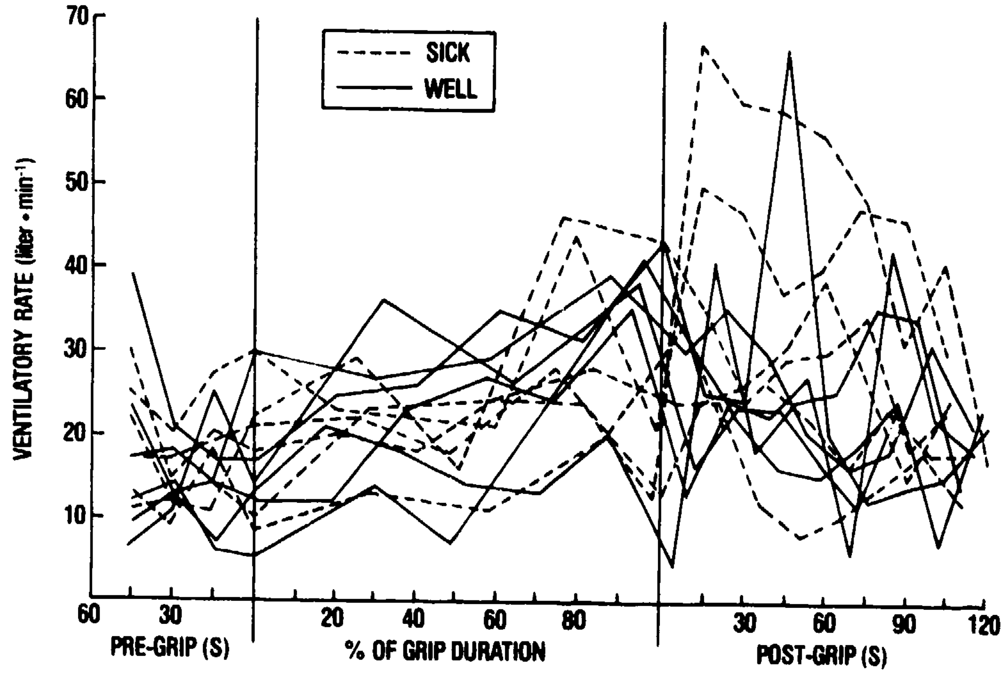

Figure 5. Ventilatory rates for each subject before, during and after the last of four isometric handgrip contractions at 4% MHS: values after 2 days' residence at 4300 meters.

An unexpected result of this study was the finding that MHS was greater during the period of altitude exposure than at sea level. There was a concomitant decrease in the endurance time (ET) of the fatiguing handgrip contractions at 40% MHS. Figure 6 shows these changes graphically. MHS was significantly elevated on days 2 and 6 at altitude (p . 0.01), while ET was below sea-level values for all handgrips. However, because of the variability in ET, these values were reduced significantly only on day 2 at altitude, for grips 2 and 4 (p . 0.05 and . 0.01, respectively).

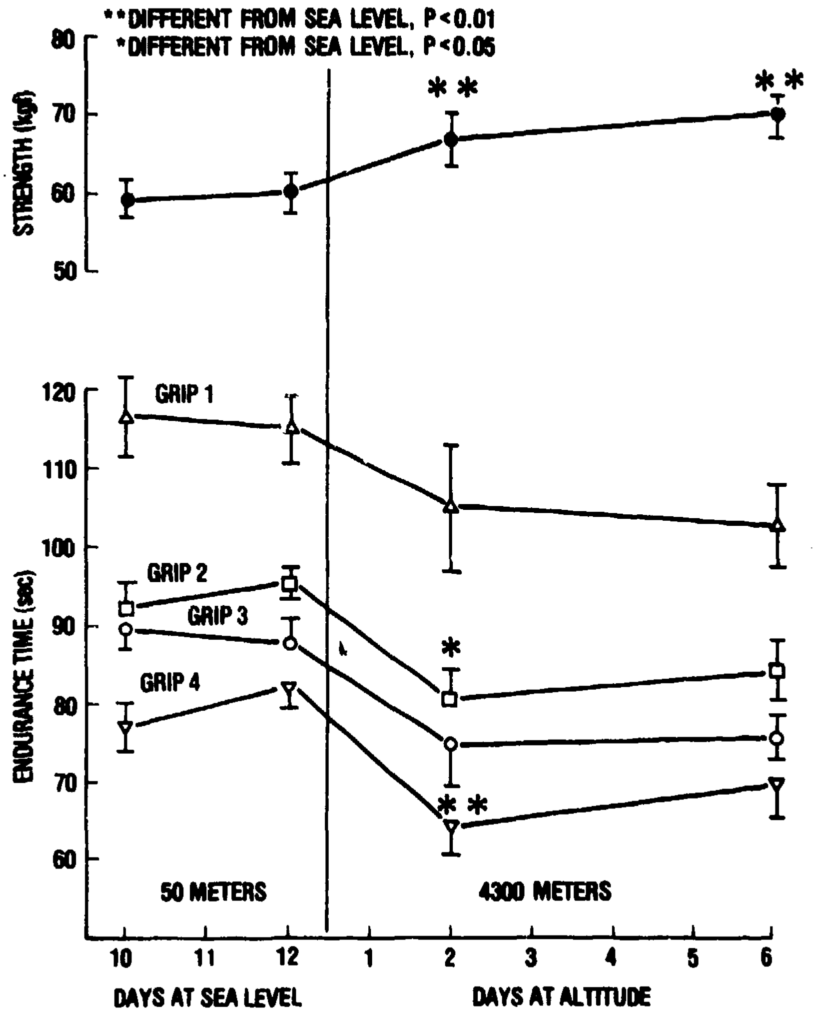

Figure 6. Maximum isometric handgrip strength (MHS) and endurance times (ET) of four isometric handgrip contractions held to complete fatigue: average values at sea level and after 2 and 6 days' residence at 4300 meters.

Table 2 expresses the strength and endurance changes in both quantitative terms and as percentages of the corresponding sea-level values. There was an increase of 11% in MHS by day 2 at altitude and an additional increase of 5% by day 6. The decreases in ET for the four endurance grips on day 2 ranged from 9-22%, averaging 15%. For day 6, the decreases in ET ranged from 11-15%, averaging 13%. Similar gains in the isometric strength of different muscle groups upon acute altitude exposure have been previously reported (7). The progressive increases in MHS throughout exposure, coupled with ET averaging 13% less by day 6 at altitude, indicate that these changes were not transient phenomena due just to acute altitude exposure, but represented a continuing muscular response to altitude.

TABLE 2

CHANGES (Δ) AND PERCENT CHANGES (Δ %) FROM SEA LEVEL VALUES OF AVERAGE MAXIMUM ISOMETRIC GRIP STRENGTH AND ENDOURANCE TIMES FOR 4 FATIGUING HANDGRIP CONTRACTIONS AFTER 2 AND 6 DAYS AT 4300 m(n=11)

	STRENGTH (kgf)	ENDURANCE TIME (sec)			
		GRIP 1	GRIP 2	GRIP 3	GRIP 4
SEA LEVEL	60.2	115	96	87	82
DAY 2 ALT.	67.0	105	80	75	64
Δ	+ 6.8**	10	16*	12	18**
(Δ %)	(+ 11.3)	(8.7)	(16.7)	(13.7)	(21.9)
DAY 6 ALT.	70.0	102	84	76	70
Δ	+ 9.8**	13	12	11	12
(Δ %)	(+ 16.3)	(11.3)	(12.5)	(12.6)	(14.6)

*Significant at $p < 0.05$

**Significant at $p < 0.01$

Although the nature of the causes of the increased MHS and reduced ET are not known, several possibilities have been eliminated. Increased motivation at altitude is unlikely to be the cause, for the SICK subjects increased more in strength after 2 days at altitude than did the WELL subjects. As shown in Table 3, the SICK subjects' MHS increased 15%, while that of the WELL subjects only 5%. Weight changes are unlikely to be the cause of the decreases in ET, as they are opposite to those shown by others to reduce ET. After 2 days at altitude, the SICK group lost an average of 4% body weight, but decreased more in ET than did the WELL group which had lost no weight. Petrofsky and Lind (8) have shown that decreases in weight are associated with gains in ET, not losses. In addition, their data suggest that MHS is not affected by changes in weight.

TABLE 3

AVERAGE CHANGES IN BODY WEIGHT, MAXIMUM ISOMETRIC GRIP STRENGTH AND GRIP ENDURANCE ON DAYS 2 AND 6 AT ALTITUDE FOR SICK AND WELL SUBJECT GROUPS

	CHANGE (% OF SEA LEVEL VALUE)			
	SEA LEVEL TO DAY 2		DAY 2 TO DAY 6	
PARAMETER	SICK	WELL	SICK	WELL
BODY WEIGHT	-4	0	-1	-2
STRENGTH	+15	+8	+5	+5
GRIP 1 ENDURANCE	-14	-5	+6	-8
GRIP 2 ENDURANCE	-19	-13	+1	+6
GRIP 3 ENDURANCE	-30	0	+8	-5
GRIP 4 ENDURANCE	-29	-16	+6	+6

Norepinephrine (NE) can affect muscle function. Alterations in plasma and urinary NE concentrations have been shown to accompany altitude exposure (9). Figure 7 shows the catecholamine concentrations before and throughout the study. Epinephrine remained essentially constant, while NE showed a progressive increase until day 4 at altitude, with a subsequent leveling off. On day 2 at altitude NE levels were not significantly elevated above sea level values yet significant strength and endurance changes had already occurred. Therefore, it is unlikely that increases in levels of circulating NE in response to altitude stress were directly responsible for the changes observed at that time.

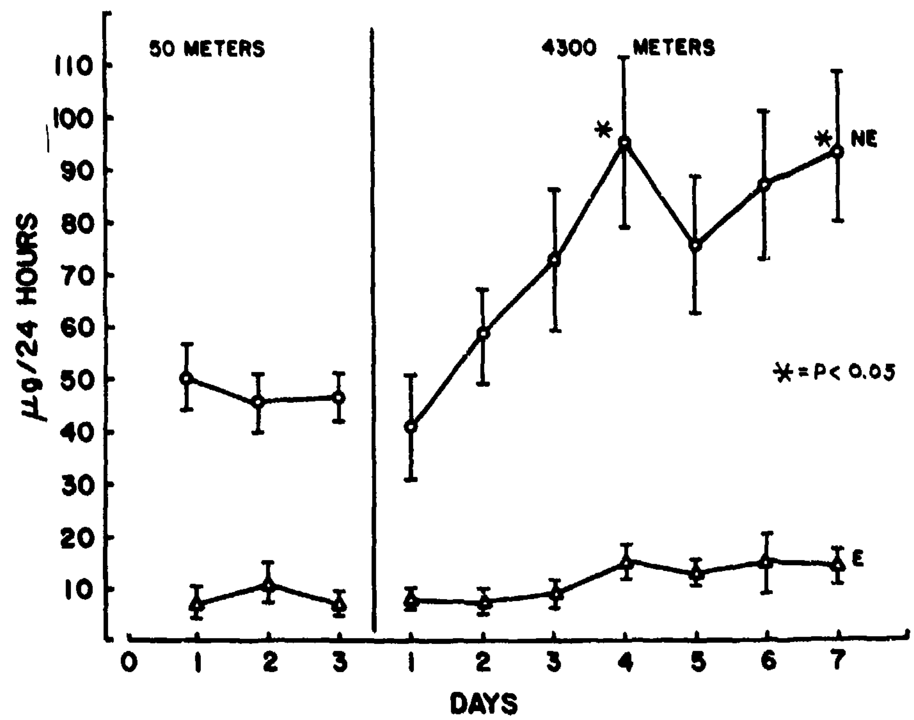

Figure 7. Urinary catecholamine excretion at sea level and throughout 7 days' residence at 4300 meters.

We conclude that the proposed test of ventilatory response to fatiguing isometric exercise at sea level does not appear to be useful, either as a predictor of ventilatory sensitivity at altitude or as a screening test to identify those individuals susceptible to moderate to severe degrees of AMS. This study does raise interesting questions concerning the control of muscle function at altitude, however, which should be explored in other studies.

Presentation:

Burse, R. L., A. Cymerman, A. J. Young and J. T. Maher. Increased isometric strength with decreased endurance at high altitude. Presented at the 64th Annual Meeting of the Federation of American Societies for Experimental Biology, Anaheim, CA 14-18 April 1980. (Abstract published in Fed. Proc. 39:289, 1980).

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Pharmacological Adjunct to High Altitude Exposure

Investigators: Richard L. Burse, Sc.D., John T. Maher, Ph.D., Milton Landowne, M.D., Allen Cymerman, Ph.D., Andrew J. Young, CPT, MSC, Ph.D.

Background:

Among the medical problems associated with abrupt exposure to high altitude are acute mountain sickness (AMS), high altitude pulmonary edema, cerebral edema and retinal hemorrhage. The most common form of altitude illness is AMS which is characterized by headache, insomnia, gastrointestinal symptoms and general malaise. Mild symptoms occur in some individuals at elevations as low as 2500 meters, whereas at 4500 meters symptoms are almost invariably present, often to the degree that a fully-trained soldier is incapable of caring for himself.

Staging, a temporary residence at an intermediate altitude prior to ascent to a higher one, is an effective method of protecting against the symptoms of AMS. However, the military requirement for troops to be rapidly deployed to high elevations, the logistics of transporting troops to intermediate elevations and the limited availability of appropriate sites in CONUS may prohibit staging to induce partial acclimatization.

Acetazolamide has been found to be useful in ameliorating symptoms when given before and continued during initial exposure, but it superimposes a metabolic acidosis and is not completely effective in preventing symptoms (1-3). The need remains to seek understanding of the mechanism of AMS and to devise superior prevention and therapy.

The present study seeks to evaluate the effectiveness of phenytoin sodium (Dilantin®) in preventing or ameliorating the symptoms of AMS. Among the well-documented actions of phenytoin is an ability to decrease the intracellular Na^+ concentration of brain tissue, and to increase the ratio of extra-to-intracellular brain Na^+ (5). The mechanism by which phenytoin acts to reduce brain Na^+ has not been established, although evidence suggests that it may alter metabolic processes involved in the passive influx or active extrusion of Na^+ from brain cells. This may prevent intracellular fluid shifts in the brain, which have been proposed as a cause of AMS (4).

Progress:

A preliminary study was performed using 6 male volunteers to assess the effect of phenytoin on the occurrence and severity of AMS symptoms in response to acute hypoxic exposure at 4575 meters in the USARIEM hypobaric chamber. The study was of double-blind crossover design. Half the subjects received phenytoin at a dosage of 0.1 g at 8-hour intervals and the other half placebo (lactose, USP) for one day prior to and during 2 days of altitude exposure. Ten days later the procedure was repeated, with administration of placebo and phenytoin reversed among subjects. Phenytoin dosage was intended to provide serum concentrations between 10 and 15 ±g·ml^{-1} during altitude exposure. Measured serum concentrations ranged from 4.4 - 13.9 ±g·ml^{-1}, as shown in Table 1.

TABLE 1

PHENYTOIN SERUM CONCENTRATION LEVELS ($\mu g \cdot m\ell^{-1}$) DURING ALTITUDE EXPOSURE. SUBJECTS PRIMED FOR 18 HOURS PRIOR TO INITIAL EXPOSURE

	Hours of Altitude Exposure		
Subject Number	2	26	50
1	10.5	6.0	10.1
2	7.4	M	M
3	7.2	6.2	4.1
4	4.4	M	M
5	9.1	6.7	W
6	9.1	8.1	13.9 M*

*Value at 36 hours, just after medical withdrawal from exposure

M = Withdrawn by medical monitor

W = Voluntarily withdrew from exposure

Results of the clinical evaluations showed that phenytoin had no markedly beneficial effects on the occurrence, severity or duration of AMS symptomatology. Table 2 shows the peak severity of symptoms as reported by subjects over the period of exposure. As symptom questionnaires were administered only in mid-morning, symptoms which peaked at other times were not reported. This had little effect on interpreting the data, as subjects who vomited or who voluntarily withdrew from the exposure can be presumed to have been suffering from AMS symptoms despite any previous reports to the contrary. Overall, one subject appeared to benefit from phenytoin, one was about the same and two were worse, subject 5 reporting more severe symptoms and subject 4

TABLE 2

PEAK SEVERITY OF SYMPTOMS FOR EACH SUBJECT WHEN PHENYTOIN (Ph) OR PLACEBO (Pl) WERE ADMINISTERED FOR 18 HOURS PRIOR TO AND THROUGHOUT 2 DAYS OF ALTITUDE EXPOSURE

	1		2		3		4		5		6	
Symptom	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl
Sleeplessness	0	0	1	0	2	2	0	3	3	2	1	0
Am tired	0	0	0	1	1	2	0	1	3	2	1	0
Difficulty concentrating	0	1	0	1	1	1	0	0	3	0	1	1
Headache	0	1	3	3	3	1	1	3	3	2	3	1
Dizziness	0	1	0	1	3	1	0	0	3	1	3	0
Weakness	0	0	0	0	3	1	0	0	3	1	3	1
Upset stomach	0	0	3	3	3	0	0	3	3	0	0	0
Nausea	0	0	3	3	3	0	0	0	3	0	3	0
Feel Sick	0	1	3	3	3	0	0	0	3	0	2	0
Other	-	-	V,M	V,M	-	W	V,M	-	W	-	M*	-
Ph effect	better		same		equivocal		worse		worse		equivocal	

Severity code: 0 = none, 1 = slight, 2 = moderate, 3 = severe

"Other" code: V = vomited

W = voluntarily withdrew from altitude exposure

M = withdrawn from altitude exposure for medical reasons

*Subject may have had upper respiratory infection vomiting with phenytoin but not with placebo. Two subjects' results were very difficult to interpret. With placebo, subject 3 displayed less severe symptoms but withdrew from the exposure during the first day. Subject 6 had more severe symptoms with phenytoin, but may have been suffering from a mild upper respiratory infection at that time. In addition, he seemed to be acutely sensitive to hypoxia, as he exhibited a dulled affect during both altitude exposures which may have affected his ability to give subjective ratings.

Comparison of serum concentrations with symptomatology showed that the 3 highest levels were in subjects 5 and 6 who had high symptom severity and in subject 1 who had the lowest. This indicates no tendency for a dose-response relationship, at least within this range of serum concentrations. Phenytoin was not without effect, however. When reported, weakness was more severe with phenytoin, while dizziness reached severe levels only with phenytoin.

Because phenytoin is widely used as an anticonvulsant drug, its effects on ventilation and cognitive/psychomotor performance were investigated. Resting ventilatory rate, shown in Figure 1, was increased by the second day at altitude. The differences could not be shown to be different due to the withdrawal of subjects prior to the second day at altitude, although an increased ventilatory

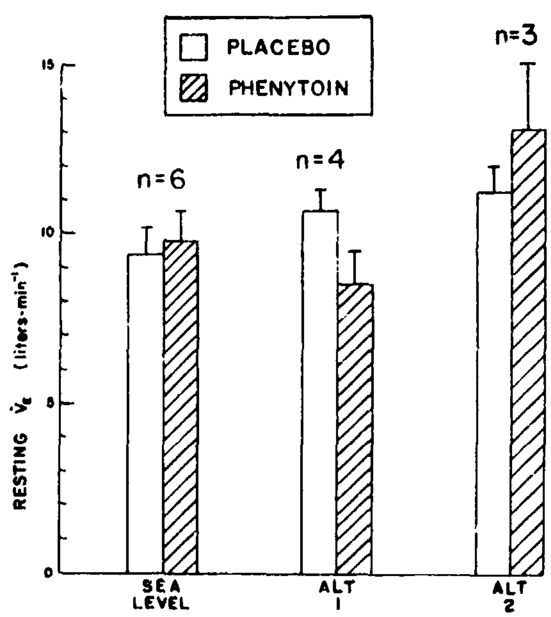

Figure 1. Effect of phenytoin on ventilatory rate at sea level and at 4575 meters.

rate is a well-known response to altitude exposure. Phenytoin did not significantly affect this response.

End-tidal P_{O_2}, a measure of alveolar O_2 tension, is shown in Figure 2. As expected, end-tidal P_{O_2} decreased throughout altitude exposure compared to sea-level (P . 0.001). Phenytoin had no effect.

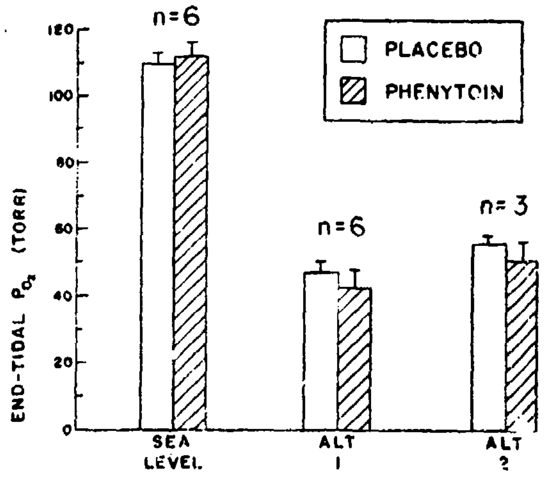

Figure 2. Effect of phenytoin on end-tidal P_{O_2} at sea level and at 4575 meters.

Figure 3 shows the results for end-tidal P_{CO_2}. Due to statistical complexities, the drop in P_{CO_2} on day 1 at altitude was significant (P . 0.05), but the drop of similar magnitude on day 2 at altitude was not. Again, phenytoin had no significant effect. These ventilatory results indicate that phenytoin did not adversely affect alveolar gas exchange. Thus its ineffectiveness in controlling AMS symptomatology did not result from a deleterious effect on gas exchange which could have masked possible beneficial effects on intracranial Na^+ transport. Since ventilation and alveolar O_2 and CO_2 tensions were the same with and without phenytoin, it appears unlikely that the drug produced any markedly beneficial effects on intracranial fluid shifts, as AMS symptoms were not alleviated.

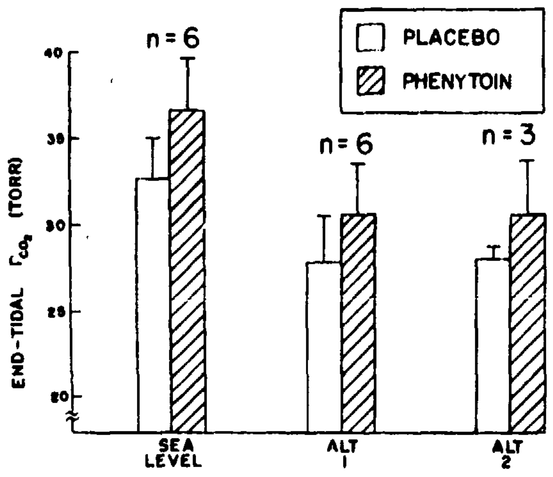

Figure 3. Effect of phenytoin on end-tidal P_{CO_2} at sea level and at 4575 meters.

A message decoding and a map reading task were performed to assess the effect of phenytoin on cognitive function. The message decoding task suffered so much from altitude exposure per se that useful results were not obtained; the map reading task showed no significant effect of phenytoin at either sea level or altitude. Performance times for the psychomotor task of gas-mask donning and doffing were almost identical with and without phenytoin and suffered very little from altitude exposure.

Phenytoin thus did not appear to be useful in the prevention or control of AMS upon acute exposure to altitude, despite whatever unmeasured intracellular effects it might have had at the serum levels obtained. Without further evidence of benefit to individuals undergoing altitude exposure, human experimentation with this drug has been discontinued. However, investigations into its effects on pulmonary hypertension in animals are continuing.

An abstract "Ineffectiveness of Phenytoin in the Control of Acute Mountain Sickness (AMS)" has been submitted for presentation at the Second International Symposium on Hypoxia and a manuscript is being prepared for publication in the open literature.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Mechanisms of Changes in Isometric Strength and Endurance at Altitude
Investigators:	Richard L. Burse, Sc.D., Andrew J. Young, CPT, MSC, Ph.D., Allen Cymerman, Ph.D. and John T. Maher, Ph.D.

Background:

An earlier study by this laboratory found that maximum isometric handgrip strength (MHS) increased 11% after 2 days' exposure to 4300 meters altitude and another 5% after 4 additional days' exposure (1). In consonance with the increased MHS, endurance times (ET) of handgrips held at 40% MHS to complete fatigue of the gripping muscles were reduced 13-15%. Factors of altered body weight, altered motivation and increased secretion of norepinephrine were provisionally eliminated as causes of the strength and endurance changes. As altered isometric strength and endurance have important implications for military performance at high altitude, particularly military mountaineering, an investigation was begun to: 1) verify the earlier findings in a different group of soldiers, 2) determine the time course of strength and endurance changes throughout an 18-day period of acclimation to altitude, 3) determine the fate of any altitude-related changes after return to sea level and 4) investigate forearm blood flow (FBF) through the gripping muscles as a possible mechanism for the observed changes.

Progress:

Nine male volunteers were trained at sea level for 13 days before providing baseline values for MHS, ET and FBF. Four successive handgrip contractions were held at 40% MHS until complete fatigue; 11 minutes rest were allowed between each contraction. The Whitney plethysmographic technique (2) was used to estimate FBF. The baseline values were compared to values obtained 1) throughout 18 days' exposure to 4300 meters on top of Pikes Peak, beginning on the second day and every other day thereafter and 2) on the third and fifth days after return to sea level. One subject voluntarily withdrew from the study at altitude.

Table 1 summarizes the results for MHS and ET for the fourth handgrip contraction (FBF data are still being analyzed). MHS for the 8 subjects who completed the study rose significantly ($P < 0.05$) from an average value of 72.3 kp during the last 3 days at sea level to an average value of 76.3 kp throughout the period of altitude exposure, a 6% difference. The values throughout altitude exposure did not differ significantly. Three days after return to sea level, the MHS was still the same as the average at altitude. By day 5 at sea level, however, the MHS had dropped to baseline values and was significantly different from day 3 back at sea level ($P < 0.05$).

The altered strength values were accompanied by reciprocally altered endurance times. Average ET decreased from 67 seconds at sea level to 62 seconds at altitude. By the third day back at sea level, ET had nearly returned to the sea level average and by the fifth day had exceeded it. However, none of the differences were statistically significant, due to test subject variability.

The observed changes in MHS are disappointing in that, though statistically significant, they do not replicate the magnitude of the changes observed in the earlier study (1). This may be due to the careful attention paid in the present experiment to the problem of training. Sufficient training in holding endurance grips to the same endpoint will produce results that are consistent from day to day. The present subjects were trained for 13 days prior to baseline data collection, while the previous subjects were trained for only 9 days. Though prior experience has shown that a well-motivated subject can achieve MHS and ET values stable to within $\pm 5\%$ after about 10 sessions, the earlier subjects may have still been "on the learning curve" when they first went to altitude. The sea-level values in the current study were quite stable, which provides confidence that the changes in function seen in the present study at altitude were not a training artifact.

Data analysis is continuing.

TABLE 1

Mean values $\pm$ SE of maximum handgrip strength (MHS) and endurance time (ET) of grip 4 at sea level (SL), throughout exposure to 4300 m altitude (ALT) and after return to SL. N= 8

Condition	Day	Mean MHS(Kp)	Mean ET (s)
SL	14	71.5 $\pm$ 3.5	65.9 $\pm$ 6.8
	15	73.2 $\pm$ 2.9	64.2 $\pm$ 6.4
	16	72.1 $\pm$ 3.1	70.0 $\pm$ 9.2
CONDITION AVG		72.3 $\pm$ 3.0	66.8 $\pm$ 7.0
ALT	2	78.7 $\pm$ 3.0	56.1 $\pm$ 2.5
	4	74.1 $\pm$ 3.3	60.8 $\pm$ 3.1
	6	74.8 $\pm$ 3.9	61.5 $\pm$ 4.4
	8	78.0 $\pm$ 4.0	60.5 $\pm$ 3.6
	10	-	-
	12	78.0 $\pm$ 5.0	65.8 $\pm$ 4.6
	14	75.0 $\pm$ 4.8	63.1 $\pm$ 5.3
	16	77.9 $\pm$ 3.7	64.0 $\pm$ 6.8
	18	76.6 $\pm$ 4.3	60.8 $\pm$ 3.5
CONDITION AVG		76.3 $\pm$ 3.8	61.6 $\pm$ 3.2
Return to SL	3	76.6 $\pm$ 4.5	65.0 $\pm$ 5.7
	5	72.4 $\pm$ 3.9	72.8 $\pm$ 9.0

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Mechanism of Enhanced Endurance During Altitude Acclimatization at 4300 Meters
Investigators:	Andrew J. Young, CPT, MSC, Ph.D., Allen Cymerman, Ph.D., Richard L. Burse, Sc.D. and John T. Maher, Ph.D.

Background:

Short-term residence at high altitude has been shown to result in increased endurance time for exercise performed at a given relative work intensity. Maher et al. (1) reported that endurance time of subjects who remained at 4300 meters for twelve days increased (day 12 vs. day 2) by 45% when measured at a work load corresponding to 75% of the subject's initial maximal oxygen uptake ($\dot{V}O_2$ max) at altitude. Horstman et al. (2) observed a 59% increase in endurance time between days 1 and 16 of residence at 4300 m. These subjects exercised at an intensity requiring about 85% of $\dot{V}O_2$ max. The investigators differ, however, in their explanation for the increased endurance. Horstman et al. (2) attributed the increase to a concomitant increase in $\dot{V}O_2$ max observed on day 15 at 4300 m and, therefore, a resultant decrease in relative work intensity. Maher et al. (1) ascribed the increased endurance after 12 days at altitude to a decrease in the anaerobic demand and rate of glycolysis as reflected by a reduction in the blood lactate concentration measured after 20 minutes of exercise at 75% $\dot{V}O_2$ max on day 12 as compared to day 1.

The decrement in $\dot{V}O_2$ max experienced by high-altitude sojourners is well documented (3,4). Although many investigators have reported this loss to be permanent (5,6), there are reports demonstrating some improvement in $\dot{V}O_2$ max during altitude sojourns of more than a few days (2,7). Even a small increase in $\dot{V}O_2$ max will result in a greatly increased endurance time; Gleser and Vogel (8) observed that a 7% increase in $\dot{V}O_2$ max was accompanied by a 100% increase in endurance time. The relationship between an individual's endurance time (t),

$\dot{V}O_2$ max, and workload is described by the equation:

$$\log(t) = A \cdot (\text{load}/\dot{V}O_2 \text{ max}) + B,$$

where A and B are constants related, respectively, to the rate and quantity of anaerobic metabolism (8). This equation shows that endurance time may be increased without an increase in $\dot{V}O_2$ max but rather by an alteration of energy metabolism in the muscle cell.

The purpose of this study was to determine if an increase in an individual's systemic oxygen transport or an alteration in substrate availability or utilization, or both, occurred during a temporary residence at 4300 meters. Either of these mechanisms could account for an increased endurance time.

Progress:

Eight male soldiers gave their consent to participate in this study after being fully informed as to the requirements and nature of the study. Subject characteristics are shown in Table 1.

TABLE 1
Physical characteristics of subjects

Subject	Age, yrs	Ht, cm	Wt, kg*
SC	23	174	68.8
RS	23	183	91.9
EB	25	183	76.5
JA	31	165	72.5
KW	22	180	74.1
TR	23	175	74.0
RM	19	170	73.5
WO	20	175	72.9
Mean	23.3	175.6	75.5
SE	1.3	2.2	2.5

*Body weight measured on first day of study

During the first 28 days of the study, sea-level control measurements were made at USARIEM (elevation 50 meters). From days 29 to 34, experimental measurements were made while the subjects were acutely exposed to hypoxia in the hypobaric chamber (pressure equivalent to 4300 meters). On day 35, subjects were transported to the summit of Pikes Peak (4300 meters) where they remained until day 55. They returned to 50 meters and post-sojourn measurements were made from day 56 to 59.

$\dot{V}O_2$ max was measured on day 1 and every seventh day thereafter, throughout the study. Intermittent exercise bouts of increasing intensity were performed on a mechanically-braked cycle-ergometer. The criterion for $\dot{V}O_2$ max was that oxygen consumption increase by less than 75 ml when work intensity was increased 180 kpm•min^{-1}. Conventional Douglas bag technique was employed to measure oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), and minute ventilation ($\dot{V}_E$). Volumes of expired air were measured with a Collins spirometer and samples of expired air were analyzed for oxygen and carbon dioxide content with Applied Electrochemistry S-3A and Beckman LB-2 analyzers, respectively. On day 3 and every seventh day thereafter, endurance was assessed. Time to exhaustion was measured while the subjects exercised at an intensity requiring 85% of their $\dot{V}O_2$max. Exhaustion was defined as inability to consistently maintain the prescribed pedal frequency (60 rpm), despite strong encouragement. After 5 minutes of exercise, and then every 10 minutes, $\dot{V}O_2$, $\dot{V}CO_2$, and $\dot{V}_E$ were measured as previously described.

In addition to the aforementioned tests of aerobic performance, the subjects performed a standardized exercise bout on days 26 (sea level, control), 33 (acute high altitude, 4300 meters), and 55 (twentieth day Pikes Peak, 4300 meters). Prior to exercise, blood samples were drawn for determination of lactate, free fatty acids and glycerol. Tissue samples of quadriceps femoris muscle were obtained (needle biopsy) for determination of glycogen levels, activity of glycolytic and oxidative enzymes, as well as fiber-type distribution. The subjects then exercised on the cycle ergometer for exactly 30 minutes at an intensity requiring 85% of $\dot{V}O_2$ max. Immediately following exercise, blood and muscle tissue samples were again obtained. Using the methods previously described, $\dot{V}O_2$, $\dot{V}CO_2$, and $\dot{V}_E$ were measured after 5, 15, and 25 minutes of exercise.

Standard procedures of ANOVA (repeated measures) were used in the analysis of the results. When a significant F ratio was obtained, Tukey's critical difference test was employed to determine the significance of differences between means. For all statistical tests, the level of significance was set at $p < 0.05$. There was no significant difference between the mean $\dot{V}O_2$ max determined during the third and fourth week of sea level experiments (3.40 and 3.39 $l \cdot min^{-1}$, respectively). There was also no significant difference between mean endurance time during the first (22.6 minutes), third (17.4 minutes) and fourth (28.7 minutes) weeks of sea level tests. Therefore, for comparisons with data from the remainder of the study, test results of the fourth week were used to represent performance at 50 meters.

Responses to maximal exercise are shown in Table 2. Acute exposure to 4300 meters (simulated) resulted in a 27% loss of maximal aerobic capacity, which was expected. There was no significant difference between $\dot{V}O_2$ max determined during the acute hypoxic exposure and that determined on the first completed day at Pikes Peak. Neither was there a significant difference between $\dot{V}O_2$ max on the first and fifteenth day at Pikes Peak. These findings are in contrast to those of Horstman et al. (2) and support the contention of others (5,6) that $\dot{V}O_2$ max does not improve after two weeks at high altitude. $\dot{V}O_2$ max at sea level was no different post-sojourn (48 hours after descent) than presojourn. There was no significant difference in maximum heart rate at sea level and at high altitude until day 15 at Pikes Peak, when a significant reduction was observed. This finding has been reported by others (9). Forty-eight hours after return to sea level, maximum heart rate was no different from the pre-sojourn value. Respiratory exchange ratio (R, calculated as $\dot{V}CO_2/\dot{V}O_2$), during maximal exercise was unaffected by acute hypoxia. Maximal R was significantly reduced, however, on the eighth and fifteenth day at Pikes Peak and this reduction persisted upon return to sea level. Although mean $\dot{V}_E$ max appeared to be higher after a week at Pikes Peak as compared to sea level, no significant differences were found.

Table 3 shows the results of endurance testing. The reduction in $\dot{V}O_2$ max at high altitude necessitated a reduction in absolute work intensity, so as to maintain relative work intensity constant for all endurance tests. Submaximal $\dot{V}_E$ and heart rate were not affected by altitude exposure. Submaximal R, while unaffected by acute hypoxic exposure, was significantly reduced during all three endurance tests at Pikes Peak and the reduction persisted upon return to sea level. Endurance time was not significantly different at any time during this study. This observation is not in agreement with the findings of two other studies (1,2).

Tissue and blood samples collected before and after the standardized work bout are presently being analyzed and results are not yet available.

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TABLE 2

Cardiovascular and respiratory responses during maximal exercise

Reponse	Sea Level Control	Acute High Altitude, 4300 m	Pikes Peak, 4300 m			Sea Level Post-Sojourn
			Week 1	Week 2	Week 3	
$\dot{V}O_2$, ($l \cdot min^{-1}$, STPD)	3.39 ± 0.11	2.48 ± 0.10*	2.40 ± 0.08*	2.40 ± 0.07*	2.44 ± 0.09*	3.46 ± 0.11
$\dot{V}_E$, ($l \cdot min^{-1}$, BTPS)	159.9 ± 5.8	164.5 ± 10.5	159.6 ± 5.8	176.4 ± 7.8	176.6 ± 8.0	163.3 ± 4.1
Heart Rate (Beats • min^{-1})	182 ± 3	166 ± 6	171 ± 4	169 ± 6	159 ± 7*	181 ± 2
R	1.26 ± 0.02	1.34 ± 0.04	1.24 ± 0.03	1.12 ± 0.04*	1.11 ± 0.04*	1.11 ± 0.04*

Values presented are Mean ± SE (n = 8)

*Significantly different from Sea Level Control

TABLE 3

Cardiovascular and respiratory responses during submaximal endurance ecercise

Response	Sea Level Control	Acute High Altitude, 4300 m	Pikes Peak, 4300 m			Sea Level Post-Sojourn
			Week 1	Week 2	Week 3	
Work Intensity ($kpm \cdot min^{-1}$)	1141 ± 56	853 ± 35*	829 ± 27*	843 ± 28*	832 ± 6*	1231 ± 55
% $\dot{V}O_2$ max	82.5 ± 1.5	87.2 ± 2.4	86.1 ± 2.7	88.5 ± 1.8	86.1 ± 1.8	87.5 ± 1.7
Heart Rate ($Beats \cdot min^{-1}$)	177 ± 4	168 ± 3	175 ± 5	168 ± 4	171 ± 3	172 ± 4
R	1.07 ± 0.02	1.05 ± 0.04	0.98 ± 0.02*	0.93 ± 0.03*	0.92 ± 0.01*	1.04 ± 0.02*
$\dot{V}_E$ ($l \cdot min^{-1}$,BTPS)	122.7 ± 5.5	124.3 ± 7.5	142.1 ± 9.3	135.4 ± 9.7	132.6 ± 6.0	133.3 ± 8.4
Endurance time, (min)	28.7 ± 3.4	41.2 ± 10.5	44.1 ± 10.7	40.5 ± 9.1	46.9 ± 8.8	28.6 ± 5.7

Values presented are Mean + SE (n = 8). Values for Heart Rate, R, and $\dot{V}_E$ are last measurements completed prior to exhaustion.

*Significantly different ($p < .05$) from Sea Level, Control

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Forearm Circulatory Responses During Exposure to High Altitude
Investigators:	Allen Cymerman, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., Charles Fulco, M.A.T. and SP5 Mary K. Miles

Background:

Rapid exposure of unacclimatized individuals to high altitude commonly results in a syndrome known as acute mountain sickness (AMS). The condition results primarily from the reduction in ambient oxygen tension, but symptoms can develop due to secondary physiological responses. Although marked inter-individual variations can occur with regard to symptom severity, intra-individual responses are characteristic and reproducible (1). In an attempt to define those individual characteristics which may have a relationship with AMS, several physiological responses were studied.

Exposure to high altitude results in stimulation of the sympathetic nervous system. The degree of stimulation as evidenced by the increased level of urinary catecholamines has been shown to be related to AMS symptom severity (2). The increased sympathetic activity has also been related to a peripheral venoconstriction which occurs during altitude exposure (3,4,5). The venoconstrictive response could lead to a rise in end-capillary pressures and an increase in organ-fluid content. With changes in both the peripheral capacitance and resistance vessels, central blood flow and pressure would be altered. This sequence of events in an individual who is a hyper-responder may relate to the central manifestations of AMS.

This study has three purposes: (1) to characterize the sensitivity of subjects on the basis of reflex vasomotor responses to selected vasoactive stimuli; (2) to determine whether the responses to these stimuli are altered by continued exposure to 4300 meters; and (3) to determine the relationship between these responses and the severity of AMS demonstrated by the subjects. It is hypothesized that those individuals who hyper-respond to these stimuli will demonstrate more severe AMS symptoms. Reflex vasomotor responses to local cold exposure, breath-holding and a hypoxic gas mixture were determined by forearm plethysmography. These responses may serve as a relatively simple test to pre-select or predict the severity of AMS and, possibly, cerebral and pulmonary edema in subjects prior to altitude exposure.

Progress:

Ten volunteers were recruited for the study. Measurements were made at sea level and during exposure to 2 hours of simulated altitude (4300 meters) in the USARIEM hypobaric chamber. Subjects were then transported to the Pikes Peak Laboratory Facility where measurements were made on days 1,2,3,5,7,9,11, and 13 of exposure.

Circulatory measurements included blood flow, venous compliance, resistance, mean blood pressure, and heart rate. These determinations were made at sea level and altitude on each subject during the following stimuli: control, breath-holding and local ice application to the neck. At sea level, measurements were also made during a hypoxic breathing test (10% O_2, 90% N_2 for 10 minutes). AMS symptoms were assessed twice daily at sea level and altitude using the Environmental Symptoms Questionnaire, a self-administered 52-item questionnaire with each item rated on a scale of 1 to 9.

The data collection phase of this study was completed during August 1980, and the analysis phase is in progress.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Self-Paced Exercise at High Altitude
Investigators:	Allen Cymerman, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., Richard L. Burse, Sc.D., James E. Wright, CPT, MSC, Ph.D. and John T. Maher, Ph.D.

Background:

The inhospitality of the high-altitude environment in which the US Army may be asked to perform requires that each individual in a unit be self-sufficient with regard to survival. This is true at least during the early phases of operations when reinforcements and resupply are least available. The load of items a soldier must physically carry is a detriment, contributing greatly to fatigue and possible incapacitation. Assuming that the load is relatively fixed, there is an optimum rate of walking that will not exhaust an individual prior to reaching the objective in a fixed-distance march.

The energy expenditure associated with load carriage while walking at sea level has been studied extensively (1,2), and some work has been done at altitude (3,4). These reports propose a concept of a fixed-energy cost per kg of total weight for movement at specific speeds and grades. Dynamic work is feasible without appreciable fatigue at 35-50% of maximal aerobic capacity. However, considering the 15-20% reduction in maximal aerobic capacity that occurs at 4300 m altitude and the changes in perception during work at high altitude (5), it is not known whether the self-paced work rate is altered at altitude and whether sea level estimates are appropriate. This study was initiated to determine: 1) the mean voluntary work output chosen by soldiers carrying a 30-kg backpack during a one-week exposure to 4300 meters; 2) the time necessary to walk 4.8 km (3 miles); and (3) the relationship between maximal aerobic capacity at sea level and performance at altitude.

Progress:

A one-man treadmill was modified so that its speed could be controlled by the subject. A pushbutton switch controlled the speed of the treadmill while the subject walked 4.8 km carrying a balanced 30-kg standard Army backpack. While walking, subjects breathed through a mouthpiece interfaced with appropriate transducers and an on-line computer which calculated oxygen uptake, carbon dioxide production, and ventilation every minute. Maximal oxygen uptake was determined at sea level and on the fourth day of altitude exposure using a standard modified Balke treadmill test.

Two 7-man groups of Army volunteers were initially recruited for the two-month study. Subjects were tested twice at sea level at least 2 weeks prior to altitude exposure and after 1,3, and 7 days' residence at Pikes Peak (4300 meters). One subject was eliminated from the altitude phase for medical reasons, and two subjects voluntarily withdrew at altitude due to severe symptoms of acute mountain sickness.

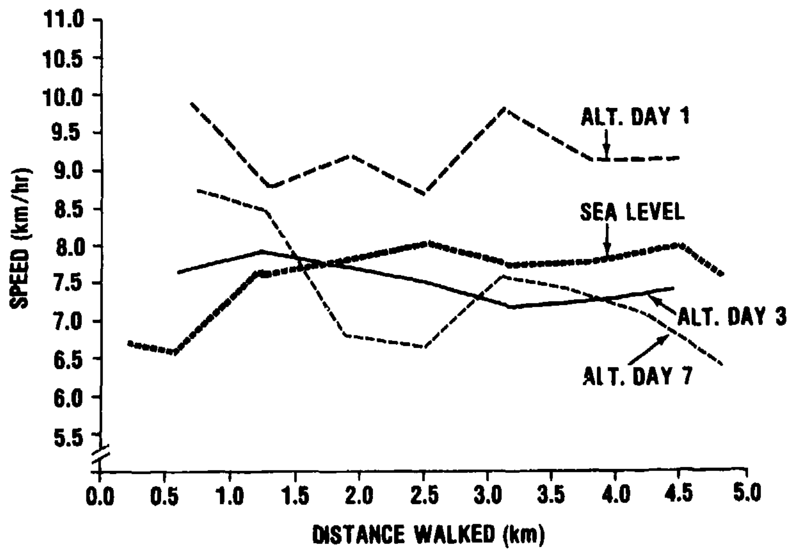

Figure 1. Voluntary changes in walking speed at sea level and altitude. Subjects walked 4.8 km on a level treadmill carrying a 30-kg backpack.

Figure 1 illustrates the average walking speed along the course of 4.8 km walk during the one-week altitude exposure. At sea level, the mean speed of working was 7.3 km/hr with no consistent changes over the 4.8 km. At altitude the mean speed of walking was 6.7 km/hr. There was no significant difference in the mean walking speed during the 7-day exposure. The reduction in walking speed resulted in an 8% increase in the time required to complete 4.8 km.

TABLE 1

Selected Physiological Responses During Self-Paced Treadmill Walking

	sea level	high altitude	P
Walking time (min)	39.3 $\pm$ 1.3	42.7 $\pm$ 0.9	< 0.01
$\dot{V}O_2$ max (m $\cdot kg^{-1}$ min^{-1})	49.4 $\pm$ 1.6	38.4 $\pm$ 1.3	< 0.001
Avg $\dot{V}O_2$ (m $\cdot kg^{-1}$ min^{-1})	25.0 $\pm$ 1.2	18.5 $\pm$ 0.9	< 0.001
% $\dot{V}O_2$ max	50.8 $\pm$ 2.2	49.1 $\pm$ 9.6	NS
Avg energy cost ($kcal \cdot hr^{-1}$)	566 $\pm$ 29	412 $\pm$ 11	< 0.001
Avg heart rate ($b \cdot min^{-1}$)	161 $\pm$ 6	166 $\pm$ 4	NS
Avg $\dot{V}_E/\dot{V}O_2$	28.6 $\pm$ 0.8	38.3 $\pm$ 1.4	< 0.001

Values represent means $\pm$ SE of 11 subjects.

As shown in Table 1 subjects also reduced their mean walking $\dot{V}O_2$ 26% in direct proportion to the reduction in $\dot{V}O_2$ max (22%). Thus, they walked at 50% of their relative $\dot{V}O_2$ whether at sea level or altitude. There were no significant differences in mean heart rates during walking at sea level or altitude although subjects exhibited a significant increase in ventilation per unit of oxygen consumption. This increase in ventilatory equivalent for oxygen may be the peripheral cue which subjects use to monitor their pace even though they were constantly informed of the distance they had walked.

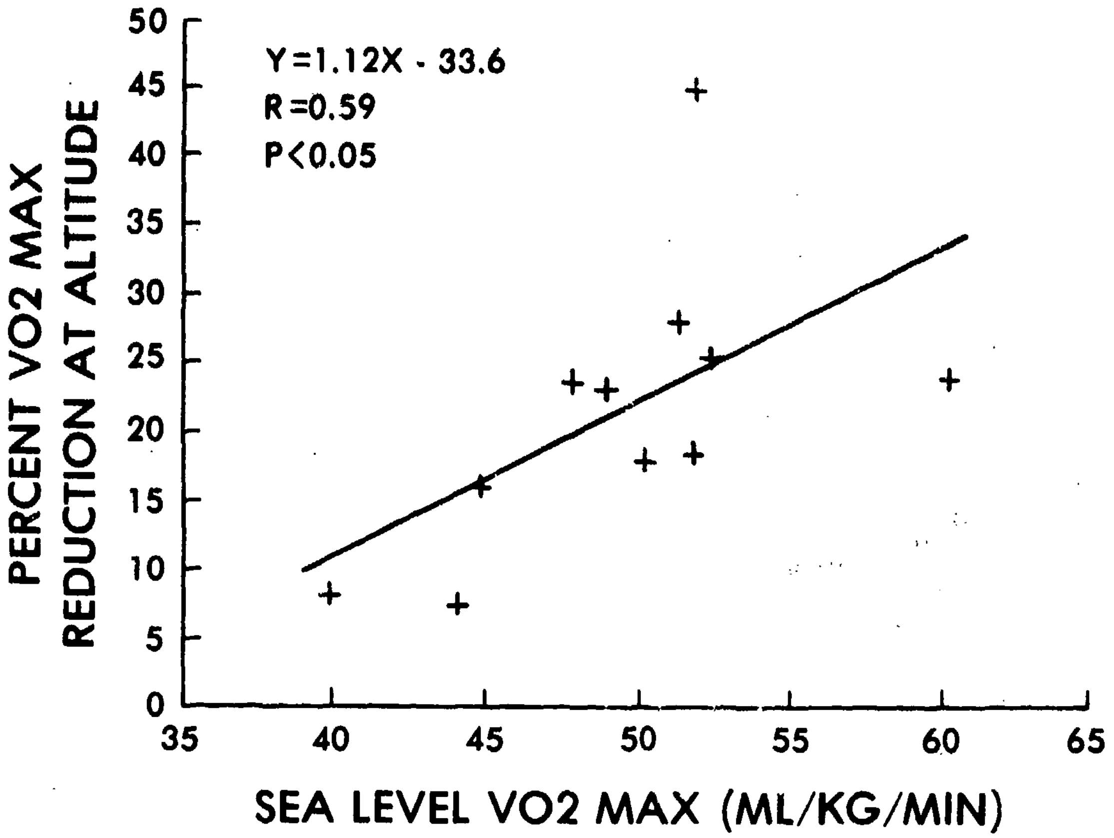

Figure 2. Relationship of sea level $\dot{V}O_2$max and the reduction obtained with exposure to 4300 meters.

There is a direct relationship between a subject's initial sea level $\dot{V}O_2$ max and the decrement that is observed at altitude (Figure 2). The greater the sea level $\dot{V}O_2$ max, the greater the percent reduction. Thus, altitude tends to reduce maximal aerobic capacity to approximately the same level in all individuals. No significant relationships were found between the time to completion of walking and $\dot{V}O_2$ max, at sea level or altitude. This suggests the importance of motivation and morale in voluntary work performance.

Presentation:

Cymerman, A., A. J. Young, R. L. Burse, J. E. Wright, and J. T. Maher. Self-paced exercise at high altitude. Presented at American College of Sports Medicine Annual Meeting, 28-30 May 1980, Las Vegas, NV, (Med. Sci. Sports Exercise 12:106, 1980).

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6148	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A879	BD	127
b. FORMER	6.27.77.A	3E162777A845	00	053
c. XXXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code)* (U)Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 016200 Stress Physiology; 013400 Psychology; 011700 Operations Research

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
75 07	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:*
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	9.0	455
	CURRENT 81	9.0	182

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: PEARLMAN, ELIOT J., LTC, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* GOLDMAN, Ralph F., Ph.D.
TELEPHONE: 955-2831
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: PANDOLF, Kent B., Ph.D.
NAME: STROSCHEIN, Leander DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Environmental Tolerance; (U)Performance Limits; (U)Energy Expenditure; (U)Terrain Coefficients; (U)Dehydration

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Develop and validate by physiological studies, mathematical models which synthesize information on military task requirements; the interaction between man, his clothing and equipment, with the environment; to predict mission performance capability identifying areas where additional information is needed.

24. (U) Predictive models of heat production and loss, subjective sensation, and limiting criteria in terms of maximum work capacity as well as unsafe levels of extremity temperature and/or body heat content are evaluated. Systems for predicting individual comfort and unit mission performance decrements and tolerance time are developed from these models. Results are validated in chamber and field trials, involving human volunteers as subjects, to guide clothing and equipment design, suggest tactical doctrine, and indicate potential environmental casualties.

25. (U) 79 10 - 80 09 Studies expanding our troop mobility prediction model for uphill and downhill terrains as well as the effects of individual fitness reveal that: (1) the energy cost of downhill walking must be predicted in a different mathematical fashion than that used to predict uphill walking; (2) male-female individual differences in fitness can be treated by using 45% of the individual's $\dot{V}O_2$ max to predict mobility, but, (3) very fit individuals may be limited by stride and step frequency before reaching the 45% $\dot{V}O_2$ max limitation. The heat stress model for predicting body temperature and tolerance time while wearing various uniforms in hot conditions has been expanded to treat the effects of solar heat load. Prediction of water requirements, and of dehydration effects on heat tolerance, has been enhanced by analysis of studies showing that the sweat rate (and water requirement in $g/m^2 \cdot hr$) can be estimated as 27.9 (Evaporative Cooling Required)(Maximum Evaporative Cooling)$^{-0.455}$ and that the expansion of blood volume which occurs during exercise/heat acclimatization will likewise occur during winter acclimatization as well as in the summer.

*Available to contractors upon originator's approval

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Comparison of Eccentric and Concentric Muscle Contractions during Various Types of Work
Investigators:	Nancy A. Pimental, Yair Shapiro, M.D. and Kent B. Pandolf, Ph.D.

Background:

During concentric contractions the muscle shortens as it contracts. During eccentric contractions the muscle is being forcibly lengthened. Although the work (force x distance) done by mirror image concentric and eccentric muscle contractions is the same, the cost of eccentric work in terms of energy expenditure is much less than that of concentric work (1-3).

Despite a lack of studies comparing eccentric to concentric work, man regularly performs eccentric work: bending, descending stairs, lowering loads, walking and running downhill. Currently there is wide variance in the literature concerning the energy cost of eccentric as compared to concentric work. Since exercise mode may be a factor in this relationship, this study employed two different modes of exercise, walking on a treadmill and cycling on a bicycle ergometer. Various exercise intensities were studied. The data can be used in making predictions of the energy cost of various tasks involving eccentric and concentric contractions.

Much of the data on downhill walking was accumulated for use in evaluating the energy expenditure prediction formula of Pandolf et al. (4), which takes into consideration the subject's weight, load to be carried, speed, type of terrain traversed and grade. The formula is used to predict the soldier's metabolic rate for a specified mission. Currently the formula is not adequate to predict for negative grades.

Progress:

Seven fit male soldiers, serving as test subjects (mean age, 20 yr, height, 176 cm, weight, 70 kg, body fat, 16%) were asked to walk on the treadmill, forward or backward, on grades ranging from -15 to + 10%, at speeds up to 1.56 $m \cdot s^{-1}$, and carrying loads up to 30 kg using the standard Army load carriage systems, positioned high on the back. On the bicycle ergometer subjects were asked to pedal either forward or backward, at exercise intensities ranging from 0 to 1600 $kpm \cdot min^{-1}$. Each exercise bout lasted 20 minutes. Energy expenditure was determined by analysis of expired air samples, and heart rate was monitored using an electrocardiogram.

Calculations of regression equations involving various types of exercise (uphill walking, downhill walking, concentric cycling, eccentric cycling) and physiological parameters (workload in $Kpm \cdot min^{-1}$, oxygen consumption in $l \cdot min^{-1}$, heart rate) were done. The results took the form of $y = a + bx$ and were as shown in the following figures.

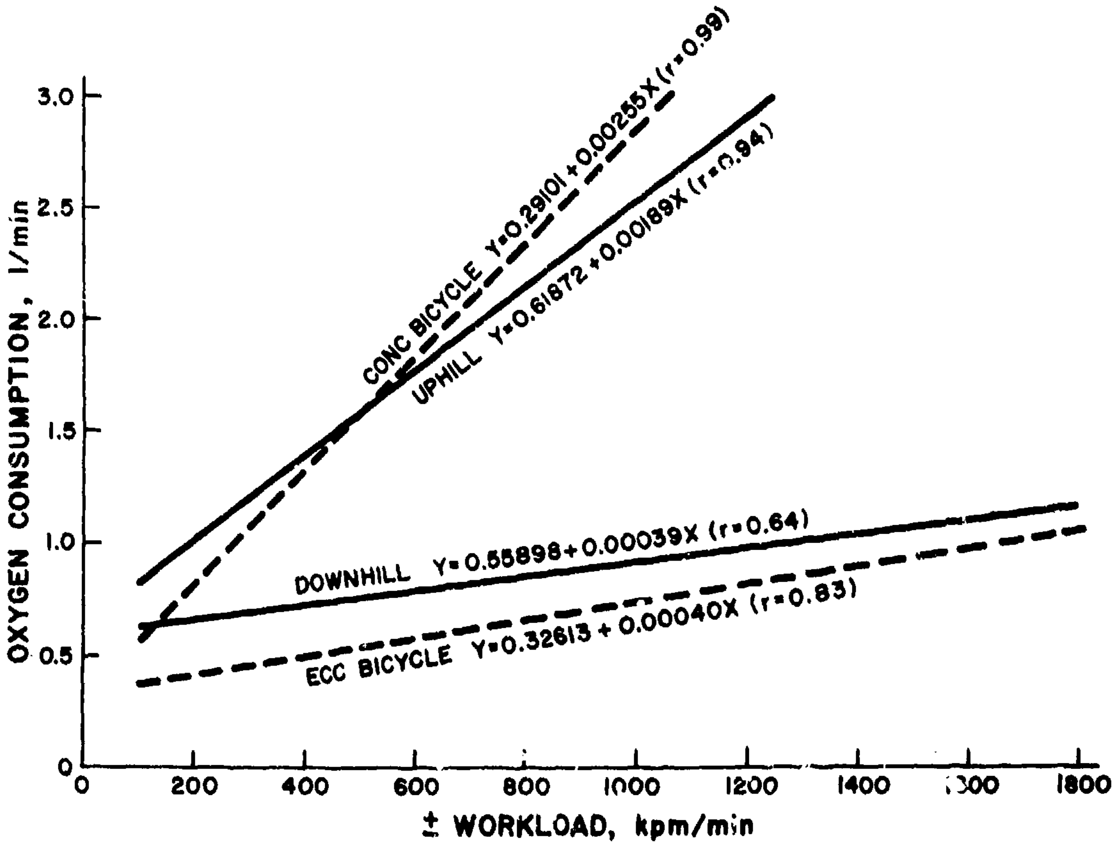

Figure 1. Regression lines of oxygen consumption vs. workload.

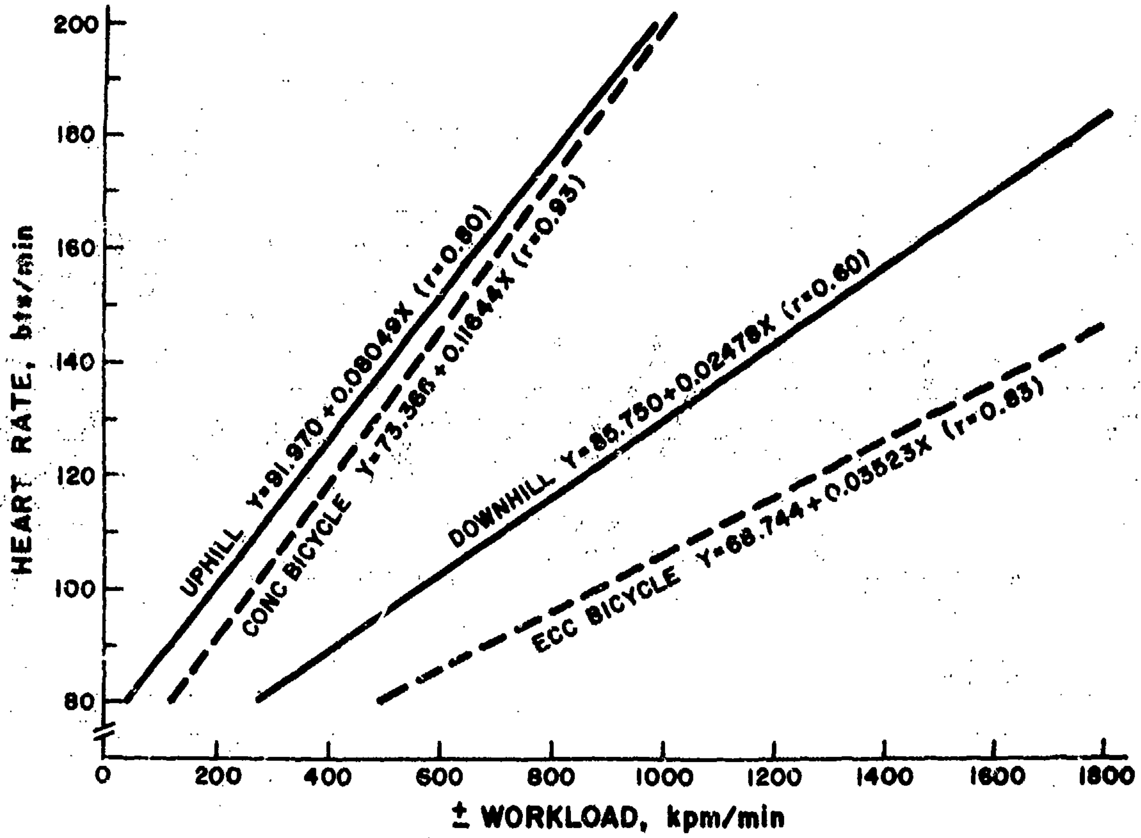

Figure 2. Regression lines of heart rate vs. workload.

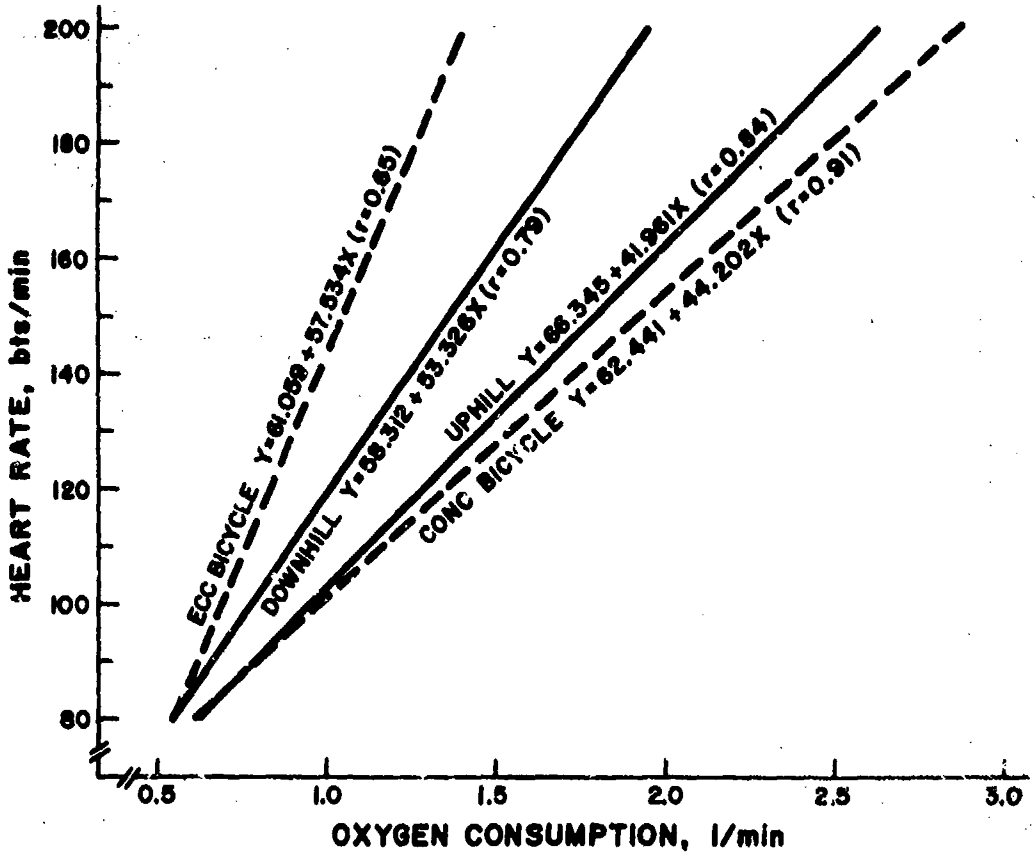

Figure 3. Regression lines of heart rate vs. oxygen consumption.

It can be seen that the regression lines for uphill walking and concentric cycling were similar, as were those for downhill walking and eccentric cycling. At equivalent workloads the oxygen consumptions and heart rates for the two eccentric conditions were much lower then for the concentric conditions, with eccentric cycling eliciting the lowest values. At similar oxygen consumptions eccentric cycling elicited the highest heart rates.

Exercise efficiencies were calculated by dividing workload by energy expenditure. The results for the five different types of exercise are shown in Table 1. Similar efficiencies were obtained for uphill walking and concentric cycling, and were the lowest of the five exercise types. Very high efficiencies were obtained for eccentric cycling. In all cases, as exercise intensity increased efficiency also increased. Efficiencies for downhill walking backward were significantly lower than for downhill walking forward ($p < 0.05$).

TABLE 1

Efficiencies for various types of exercise (%).

Average Exercise Intensity (kpm/min)	Range	Uphill Walking	Downhill Forward	Downhill Backward	Conc Cycling	Ecc Cycling
172	142-202	8.8	13.4	11.2	----	----
287	237-337	10.3	18.4	14.0	12.0	----
344	283-404	13.8	27.8	22.6	----	----
401	330-471	----	18.6	----	----	----
515	425-606	----	37.8	----	----	----
573	472-673	15.5	37.4	30.0	15.4	40.2
802	661-942	----	41.2	----	----	----
850	850	19.0	----	----	16.2	----
860	710-1010	----	51.3	----	----	57.7
1203	991-1414	----	55.9	----	----	70.5
1416	1416	----	----	----	----	73.7
Mean		13.49	33.54	19.46	14.54	60.55
± SD		±0.63	±1.06	±1.05	±0.45	±2.77

The energy expenditure values obtained in this study for level and uphill walking were compared to those values predicted by the formula of Pandolf et al. (see Table 2). For walking uphill at 1.12 $m \cdot s^{-1}$ the formula was accurate ($p < 0.05$). At 0.67 $m \cdot s^{-1}$ the predicted values were significantly lower than actual. For level walking the prediction formula underestimated by 14 to 33%. This suggests that the current formula may over-emphasize the effects of speed and load on energy expenditure while walking at very slow speeds.

TABLE 2

Actual vs. predicted energy expenditure (watt).

Speed (m/s)	Grade (%)	Load (kg)	Actual	Predicted	Difference (%)	Significance
0.67	+ 5	0	280	236	16	P<.01
0.67	+ 5	15	313	271	13	P<.01
0.67	+ 5	30	364	328	10	P<.01
0.67	+10	0	345	318	8	P<.01
0.67	+10	15	401	371	7	P<.01
0.67	+10	30	467	445	5	P<.02
0.67	+30	0	731	648	11	P<.01
1.12	+ 5	0	389	376	3	NS
1.12	+ 5	15	439	442	-1	NS
1.12	+ 5	30	529	528	0	NS
1.12	+10	0	511	514	0	NS
1.12	+10	15	595	609	-2	NS
1.12	+10	30	699	725	-4	NS
0.67	0	0	215	153	28	P<.01
0.67	0	15	255	171	33	P<.01
1.12	0	0	294	238	18	P<.01
1.12	0	15	318	274	14	P<.01

Presentation:

Pimental, N. A., Y. Shapiro, and K. B. Pandolf. Comparison of physiological responses to various types of exercise: uphill and downhill walking and concentric and eccentric cycling. Paper delivered at the 20th Annual Brouha Work Physiology Symposium, Cambridge, Massachusetts, September 17-19, 1980.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment
Study Title:	Troop Mobility as a Function of Load and Terrain
Study Sub-Title:	Self-Paced Hard Work Comparing Men and Women
Investigators:	Fred R. Winsmann, William J. Evans, Ed.D., Kent B. Pandolf, Ph.D. and Ralph F. Goldman, Ph.D.

Background:

Soldiers in a maneuver or combat operation often are required to traverse a variety of terrains at self-paced (rather than fixed-paced) velocities to accomplish an assigned mission. Tactical considerations sometimes dictate troop movement through heavy brush, as well as over most other types of terrain, while carrying basic fighting and subsistence loads. Therefore, the capability of assessing and predicting troop mobility over a variety of terrains while carrying loads is an important military concern for combat operations.

The energy expenditure of walking has been extensively investigated (2, 4). It has been shown that external load, speed, body weight, terrain, and slope all have a direct effect on energy expenditure; these relationships are constant and predictable (2, 5, 6). Recently, Pandolf et al. (5) have revised the original predictive formula of Givoni and Goldman (2) for determining energy expenditure for walking and load carrying. This current formula was developed to include standing or walking speeds up to ($\sim 2.4\ m \cdot s^{-1}$), grades from 0 to 25% loads from 0 to 70 kg and various terrains.

Previous studies (3, 7) investigating maximal voluntary hard work rates of soldiers have shown that walking velocity can be predicted over a variety of terrains. Man will select an energy expenditure (watt) of approximately 494 watts $\pm$ 10% when requested to self-pace at a hard work rate (3). For physically fit individuals this represents 40 to 50% of their maximal aerobic power ($\dot{V}O_2$ max). By using the current prediction formula, energy expenditure can be accurately predicted where the load carried, speed, body weight, terrain and slope are known.

It seems reasonable to hypothesize that women or troop units of different physiological states and/or lower levels of physical fitness (i.e. $\dot{V}O_2$ max and body composition) would adopt different self-pacing hard work rates and therefore have different mobility rates. Therefore, a voluntary rate of 494 watts $\pm$ 10% cannot be assumed for females. The present study compared voluntary hard work rates of males and females on four different terrains.

Progress:

Six healthy male and six healthy female soldiers volunteered to participate in this study. The men had an average age (mean $\pm$ SE) of 22.8 $\pm$ 0.9 yr; height (nude), 171.1 $\pm$ 2.8 cm; weight (nude), 66.7 $\pm$ 2.7 kg; body fat, 16.2 $\pm$ 2.0% determined by the method of Durnin and Womersley (1) and maximal oxygen uptake, 2.25 $\pm$ 0.11 $mmol \cdot kg^{-1} \cdot min^{-1}$ (50.3 $\pm$ 2.5 $ml \cdot kg^{-1} \cdot min^{-1}$) while the women had a mean age of 22.3 $\pm$ 1.1 yr; height (nude), 162.7 $\pm$ 2.4 cm; weight (nude), 57.1 $\pm$ 4.3 kg; body fat, 27.5 $\pm$ 2.3%, and maximal oxygen uptake of 1.83 $\pm$ 0.08 $mmol \cdot kg^{-1} \cdot min^{-1}$ (41.1 $\pm$ 1.8 $ml \cdot kg^{-1} \cdot min^{-1}$).

Initially, maximal oxygen uptake ($\dot{V}O_2$ max) was determined for each subject according to the methods of Taylor et al. (8) using a Quinton treadmill. All subjects were monitored electrocardiographically. During these tests, expired air was collected in Douglas bags; the volume was measured in a Collins Spirometer and converted to standard environmental conditions (STPD); and the O_2 and CO_2 concentrations were measured with an Applied Electrochemistry Model S-3A O_2 analyzer and Beckman LB-2 infrared CO_2 analyzer. The method of Weir (9) was used to calculate oxygen uptake ($\dot{V}O_2$).

The subjects were then taken to a field site previously used for such investigations. Each subject walked over a total of four different terrains with three different external loads: 0, 10 and 20 kg backpacks. The loads were randomly assigned to the subjects on each of three successive days. No subject carried more than one external load on a given day. The four terrains consisted of heavy brush (1.3 km), light brush (1.4 km), dirt road (1.8 km), and blacktop road (1.6 km). The four terrains were traversed consecutively during each trial. The terrain coefficients (η) for each had been previously determined by this laboratory: blacktop road (BR) = 1.0, dirt road (DR) = 1.1, light brush (LB) = 1.2, and heavy brush (HB) = 1.5 (6).

On each day all subjects were requested to walk over all four terrains in as short a time as possible. Investigators were stationed at the start and finish of each terrain to record individual terrain times and the total time on the course. Final heart rate for each terrain was recorded by palpation. Daily rewards and an overall best 3-day time award were given to the male and female with the shortest time on the course. Relative humidity and ambient temperature were recorded at 15-minute intervals while subjects were on the course.

Results:

The mean time to traverse the course (6.1 km) for the males was 55.3 minute (range, 45.0 minute, 0 kg; 87.6 minute, 20 kg) and for the females was 65.6 minute (range, 46.9 minute, 0 kg; 122.5 minute, 20 kg). The average energy expenditure (watt) of the males on all terrains with each external load was found to be significantly and consistently higher than the females' ($p < 0.05$) with each external load carried as illustrated in Figure 1. Females are seen to be remarkably consistent in maintaining the same self-paced "hard" energy expenditure regardless of the load. Table 1 presents the average speeds and energy expenditures for each individual terrain at each load for the males and females. Speed is seen to be consistently lower for the females at each terrain and load. The mean energy expenditure for the males with no load on all four terrains was 552 watts, 52% greater than the mean of 365 watts for the females. Carrying 10 kg, the mean energy expenditure for the males was 510 watts, 39% higher than the 366 watts mean of the females. Carrying 20 kg, the cost for the males was an average of 583 watts, 60% greater than the 364 watts value for the females.

The mean $\dot{V}O_2$ max values for the males (2.25 ± 0.11 mmol•kg^{-1}•min^{-1} (50.3 ± 2.5 ml•kg^{-1}•min^{-1}) and females (1.83 ± 0.08 mmol•kg^{-1}•min^{-1} ($41.1 + 1.8$ ml•kg^{-1}•min^{-1}) are statistically different ($p < 0.05$). However, both groups would be classified as "average" based on sex and age in their ability to perform endurance work according to their $\dot{V}O_2$ max. When the energy expenditures in this study were expressed as relative energy expenditure (% $\dot{V}O_2$ max), the averages for the males and females at each load are very similar as seen in Figure 2. The means for the males carrying no load, 10 kg and

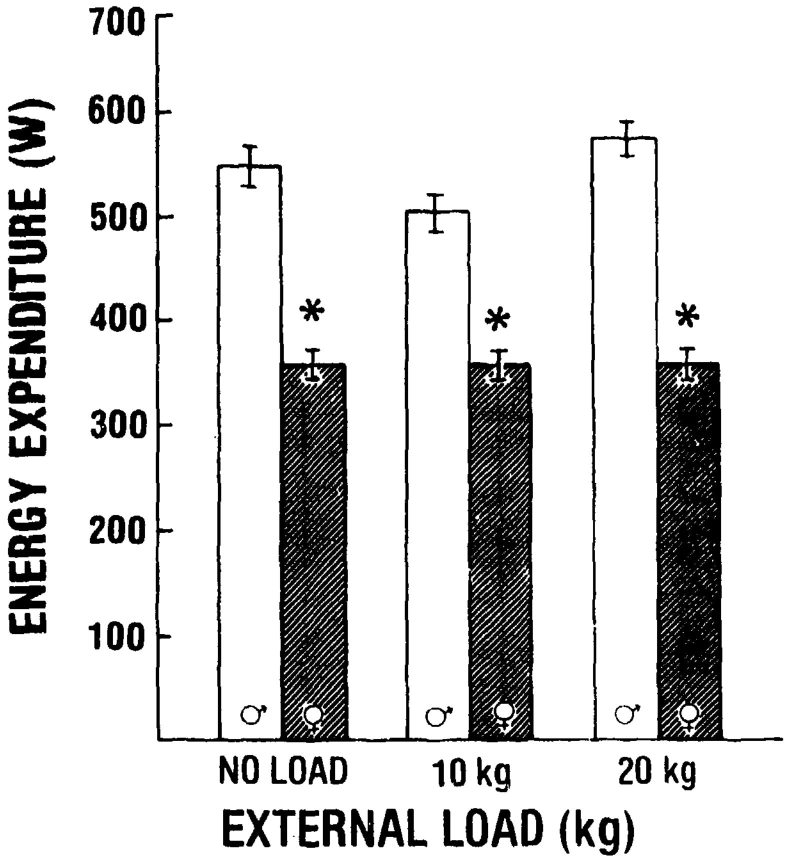

Figure 1. The relationship between males and females of the average predicted energy expenditure (W) on all terrains with each external load.

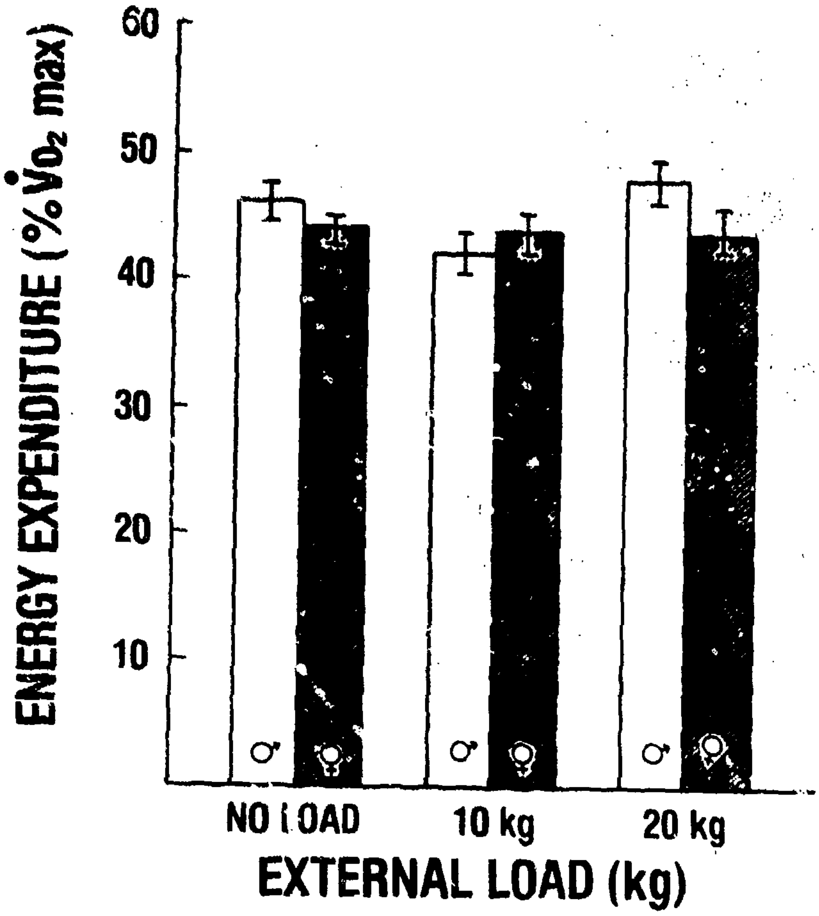

Figure 2. Comparison between males and females of the relative exergy expenditure calculated as percent of maximal aerobic power (% $\dot{V}O_2$ max) over all terrains with each external load.

20 kg were 46, 43 and 48% $\dot{V}O_2$ max respectively, while the average for the females was 44% $\dot{V}O_2$ max for each load (see Table 1). None of these differences in relative energy expenditure between the sexes was significant ($p > 0.05$).

Table 2 compares the prediction of overall speed (m s^{-1}) for all four terrains at each load based on 494 watts and 45% $\dot{V}O_2$ max to the actual speed. Generally, the prediction based on 45% $\dot{V}O_2$ max was found to be a slightly better predictor of speed at each condition than 494 watts for both males and females. There were significant correlations between the predicted speed, using both 494 watts and 45% $\dot{V}O_2$ max, and actual speed for males and females. However, the correlations for the females were significantly higher than those for the males.

In summary, these data suggest that the voluntary hard work rate depends upon aerobic capacity. The best predictor of speed on each terrain for this work of one to two hour duration is 45% $\dot{V}O_2$ max. This also suggests that a value close to 45% $\dot{V}O_2$ max may be a better predictor of troop mobility for heterogenously fit populations than the maximal voluntary pace of 494 watts $\pm$ 10%. The men tended to adjust their individual pace much closer to 494 watts $\pm$ 10% than did the women, but both men and women worked at nearly the same percent of their maximal aerobic power for the one to two hour duration throughout the study.

TABLE 1

Comparison between males and females of self-paced speed, energy cost and percent of maximal oxygen uptake to traverse four different terrains.

External Load	0 kg			10 kg			20 kg		
	Speed $m\ s^{-1}$	Energy Cost W	% $\dot{V}O_2max$	Speed $m\ s^{-1}$	Energy Cost W	% $\dot{V}O_2max$	Speed $m\ s^{-1}$	Energy Cost W	% $\dot{V}O_2max$
<u>Male</u>									
HB	1.75	532	64	1.52	505	42	1.54	579	48
DR	2.03	522	43	1.76	463	39	1.81	544	45
BR	2.16	572	48	1.92	527	44	1.91	593	49
LB	1.97	555	46	1.82	547	46	1.83	615	51
Mean	1.98	552	45.8	1.75	510	42.5	1.77	583	48.2
SE	0.05	21.5	1.5	0.05	18.1	1.8	0.04	17.0	1.6
<u>Female</u>									
HB	1.38	327	39	1.25	334	40	0.99	324	40
DR	1.76	350	42	1.63	359	43	1.48	363	44
BR	1.91	390	47	1.74	398	48	1.59	398	48
LB	1.78	392	48	1.56	376	45	1.40	372	45
Mean	1.70	365	44.1	1.54	366	44.1	1.40	364	44.2
SE	0.05	11.9	1.2	0.04	15.4	1.6	0.05	15.4	2.0

HB, heavy brush; DR, dirt road; BR, blacktop road; LB, light brush

TABLE 2

Actual speed compared to predicted speed for males and females based on self-paced rates of 494 watts and 45% $\dot{V}O_2$ max.

	Actual Speed $m\,s^{-1}$		Predicted Speed at 494 watts $m\,s^{-1}$		Predicted Speed at 45% $\dot{V}O_2$ max $m\,s^{-1}$	
	Male	Female	Male	Female	Male	Female
No load	$1.98 \pm .05$	$1.70 \pm .05$	$1.88 \pm .04$	$2.07 \pm .05$	$1.99 \pm .04$	$1.73 \pm .04$
10 kg	$1.75 \pm .05$	$.54 \pm .04$	$1.73 \pm .03$	$1.89 \pm .05$	$1.84 \pm .04$	$1.58 \pm .04$
20 kg	$1.77 \pm .04$	$1.40 \pm .05$	$1.60 \pm .03$	$1.73 \pm .04$	$1.70 \pm .04$	$1.43 \pm .03$
Grand mean	$1.83 \pm .03$	$1.55 \pm .03$	$1.73 \pm .02$	$1.90 \pm .03$	$1.84 \pm .03$	$1.58 \pm .02$
Correlation with actual speed	-	-	0.59	0.70	0.58	0.70

Presentation:

Evans, W. J., F. R. Winsmann, K. B. Pandolf and R. F. Goldman. Self-Paced Hard Physical Work Comparing Men and Women. Paper delivered at Brouha Work Physiology Symposium, Cambridge, MA, September 1980.

Publication:

Evans, W. J., F.R. Winsmann, K.B. Pandolf and R.F. Goldman. Self-Paced Hard Physical Work Comparing Men and Women. Ergonomics 1980, in press.

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Program Element;	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Troop Mobility as a Function of Load and Terrain
Study Sub-Title:	Prolonged Self-Paced Hard Work Comparing Trained and Untrained Men
Investigators:	Fred R. Winsmann, William J. Evans, Ed.D. and Kent B. Pandolf, Ph.D.

Background:

Soldiers are often required to walk at self-paced velocities over a variety of terrains to accomplish an assigned mission. Necessarily, these troops must reach their destinations in as short a time as possible. Previous self-pacing studies by this laboratory have demonstrated that moderately fit males will naturally "select" a metabolic output of 494 watts $\pm$ 10% when requested to walk at as fast a pace as possible (3). More recently, in a study comparing voluntary hard work rates of males and females, Evans et al. (2) showed that both males and females tend to choose a metabolic output that corresponds to 45% of their maximum aerobic power ($\dot{V}O_2$ max). These authors indicated that the voluntary hard work rate is dependent upon maximal aerobic power.

These self-pacing studies (2, 3, 8,) subjects walked for 1 to 1½ hours only. However, troop movements may often require a continuous march for extended periods of time. Some recent investigations (4, 6) have suggested that well-trained subjects exercising at self-paced intensities for prolonged periods of time may reduce their metabolic output to below 40% $\dot{V}O_2$ max.

It is well known that aerobic training increases endurance performance. A well-trained individual could reasonably be expected to self-pace at a higher metabolic output and to maintain this pace for a longer period of time than an untrained person. This investigation compared the speed and metabolic output (W) of a group of trained and untrained (sedentary) males walking on four different terrains for an extended period of time.

Progress

Six healthy trained and six healthy untrained (sedentary) male subjects were chosen for participation in this study based on their current activity habits and $\dot{V}O_2$ max. The trained subjects had an average age (mean $\pm$ SE) of 25 $\pm$ 1 yr; height (nude), 180 $\pm$ 2 cm; weight (nude), 72.3 $\pm$ 3.8 kg; body fat, 13.2 $\pm$ 1.0% determined by the method of Durnin and Womersley (1) and maximal oxygen uptake ($\dot{V}O_2$ max) 2.63 $\pm$ .11 mmol$\cdot$kg$^{-1}\cdot$min^{-1} (59.0 $\pm$ 2.5 ml$\cdot$kg$^{-1}\cdot$min^{-1}) while the untrained group had a mean age of 24 $\pm$ 1 yr; height (nude), 175 $\pm$ 2 cm; weight (nude), 73.3 $\pm$ 4.5 kg; body fat, 14.2 $\pm$ 1.8%; and $\dot{V}O_2$ max of 2.01 $\pm$ .05 mmol$\cdot$kg$^{-1}\cdot$min^{-1} (45.1 $\pm$ 1.2 ml$\cdot$kg$^{-1}\cdot$min^{-1}).

Prior to participation in the self-paced work portion of this investigation, $\dot{V}O_2$ was determined for each subject according to the methods of Taylor et al. (9) using a Quinton treadmill. All subjects were monitored electrocardiographically during the test. Expired air was collected in Douglas bags; the volume was measured in a Collins spirometer and converted to standard environmental conditions (STPD) and the O_2 and CO_2 concentrations were measured with an Applied Electro-Chemistry Model S-3A O_2 analyzer and Beckman LB-2 infrared CO_2 analyzer. The method of Weir (10) was used to calculate oxygen consumption ($\dot{V}O_2$).

The subjects were then taken to a field site previously used for such investigations. Each subject walked over a total of four different terrains with three different external loads: 0, 10, and 20 kg backpacks. The loads were randomly assigned to the subjects on each of three successive days. No subject carried more than one external load on a given day. The four terrains consisted of heavy brush (1.3 km), light brush (1.4 km), dirt road (1.8 km), and blacktop road (1.6 km). The four terrains were traversed consecutively during each round. On each day all subjects completed three consecutive rounds (18.3 km). The terrain coefficients (η) for each had been previously determined by this laboratory: blacktop road (BR) = 1.0, dirt road (DR) = 1.1, light brush (LB) = 1.2, and heavy brush (HB) = 1.5 (7).

All subjects were requested to walk the entire distance in as short a time as possible. Investigators were stationed at the start and finish of each terrain to record individual terrain times and the total time on the course. Relative humidity and ambient temperature were recorded at 15-minute intervals while the subjects were on the course. Final heart rate (HR) for each terrain during each round was measured by palpation. A reward was given to the subject from each group with the best overall time for the three days of testing.

Individual energy expenditures for each terrain were predicted using the method of Pandolf et al. (5) given the particular external load, calculated walking velocity, body weight, and specific terrain; the overall slope of the course was assumed to be zero. A mixed factorial analysis of variance was used to assess significant differences ($p < .05$). Each subject received all combinations of the "factors" (4 terrains, 3 loads, 3 trials) but with the subjects divided into two groups (trained and untrained).

Results:

Walking velocity and energy expenditure were not different between the two groups ($p > .05$), and did not decline with time as the subjects traversed the course for any of the load carriage conditions. Relative energy expenditures, however, were significantly different ($p < .05$) between the trained and the untrained subjects (mean for all conditions = 35% $\dot{V}O_2$ max and 45% $\dot{V}O_2$ max respectively). Mean heart rate for the untrained group was also significantly greater than that of the trained group over all four terrains ($p < 0.05$). These data indicate that when men are required to do self-paced hard work of an extended duration their walking velocity and metabolic output will remain constant. Fit individuals may be limited by an inability to walk fast enough to maintain the same relative energy expenditure as the unfit group. Consequently, the fit group could be expected to be capable of further extending the amount of work performed without a significant fall in metabolic output.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Establishing Terrain Coefficients for Predicting the Energy Cost of Oversnow Movement Aided by Military Skis and Snowshoes

Investigators: Fred R. Winsmann and Gerald W. Newcomb

Background:

Previous studies in the Military Ergonomics Division have defined coefficients for predicting the energy cost of walking in combat boots at a fixed pace on specific terrain relative to the energy cost of walking on treadmills (1, 2). Coefficients for 6 terrains (Blacktop Road, Dirt Road, Light Brush, Heavy Brush, Sand, Swamp) devoid of snow were first established in 1972 (4, 5). More recently, coefficients for walking in snow have been defined as a function of the depth of footprint (2) to extend the energy cost of the prediction equation for military foot movement reported in 1971 (1). To include oversnow movement in Arctic footwear, with skis and snowshoes terrain coefficients are needed for the energy cost of:

a. Fixed-pace snow walking in the current Army standard cold-dry vapor barrier boot.

b. Fixed-paced snowshoeing and cross-country skiing, utilizing current Army standard equipment.

We expected that the energy cost would be greater due to the added weight of the footwear and oversnow equipment (4), but the added cost cannot be predicted accurately because of differences in traction, penetration in the snow and snowloading of skis and snowshoes. Although the energy cost of oversnow movement on skis and snowshoes of civilians has been studied, this information cannot serve as a data base for prediction because the subjects are generally very skillful, highly fit subjects of varying ages, most often using recreational or competitive equipment which is much lighter in weight than that provided the less experienced US soldier.

Progress:

During the winter of 1977-78, energy cost data were collected from 10 subjects carrying 5.8 kg packloads, 6 subjects carrying 15.8 kg loads and 2 subjects carrying 25.8 kg loads as they snowshoed for 30 min on a packed trail. Speeds were 0.67, 0.89 and 1.34 $m \cdot s^{-1}$ (1.5, 2 and 3 mph); speeds below 1.5 mph were found too slow for the maintenance of proper balance. Depending on the individual, the weight of clothing, boots and snowshoes added from 6.7-10.1 kg to the total load.

Energy cost data is shown in Table 1 for the 6 subjects who carried 5.8 and 15.8 kg loads at the 3 speeds. Analysis of variance showed that speed affected the energy cost of snowshoeing significantly ($p < 0.01$), while increasing the pack weight 10 kg did not. Quite possibly, the 10 kg increment in pack weight added only a relatively small amount to the metabolic cost of transporting the total load of body, pack, clothing and foot gear. This possibility can be explored statistically when data from a larger sample of individuals is collected.

TABLE 1

Comparison of Measured (meas) and Predicted (pred) Energy Costs of Snowshoeing and Calculated Terrain Coefficients (η) as Related to Speed and Pack Weight, Means of 6 Subjects ± Standard Error

Speed ($m \cdot s^{-1}$)	Pack Weight (kg)	Energy Cost (watts) meas	pred	η
0.67	5.8	317 ± 23	175 ± 12	3.4 ± 0.2
	15.8	335 ± 19	196 ± 10	3.1 ± 0.2
0.89	5.8	418 ± 94	221 ± 15	2.9 ± 0.3
	15.8	418 ± 19	247 ± 13	2.5 ± 0.1
1.34	5.8	615 ± 39	351 ± 23	2.1 ± 0.1
	15.8	674 ± 36	39[illegible] ± 22	2.1 ± 0.1

The predicted energy cost of carrying the same total weight as a single load on a blacktop road (3) is also shown in the "pred" column in Table 1. Comparison of the measured and predicted values shows the energy cost of snowshoeing to range from 1.7 to 1.9 times that of road walking, irrespective of speed or pack weight. The overall average factor is 1.76, with a very small standard deviation of 0.08. If this preliminary estimate is confirmed by data from a larger sample carrying the same loads and for heavier loads, then snowshoeing on a level, packed trail is about 75% more difficult than carrying the same total load on a hard surface road.

In all the other terrains investigated, including snow walking (1, 2, 5) only the speed term needed correction by a terrain factor (symbolized by η) to predict adequately the energy cost. This is the first time that one overall multiplier for the entire energy cost equation was required in order to express the effect of terrain on energy cost. However, such a result is not unreasonable, as the present energy cost prediction equation (3) consists predominantly of terms for load bearing while standing and walking on the level each of which may be affected by a different aspect of snowshoeing on a level trail.

Just lifting the legs with no forward motion while bearing the weight of the snowshoes, boots and extra cold weather clothing may well involve added muscular effort in order to maintain balance, particularly on slippery snow surfaces. This is shown by the difficulty in maintaining balance while walking on snowshoes at very slow speeds. It was obvious that subjects walked with the legs spread apart in order to prevent stepping on the inside edges of the snowshoes. This induced a side-to-side rocking motion which disturbed normal balance and quite reasonably could have induced a large increment in the energy cost of just moving the feet in place. Forward motion also requires more energy when hobbled by cold weather clothing and with additional weight on the extremities (4, 6). Correction of back- or side-slip of the snowshoes also adds another increment to the energy cost.

In order to determine the overall for the total energy cost equation, the sample of subjects walking at the 3 speeds and wearing the 3 pack loads should be enlarged. In addition a separate study of the energy cost of breaking trail is required to assess the metabolic effects of different depths of unbroken snow, not addressed in the current study, but necessary for applying the energy cost prediction equation to the battlefield environment.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Operational Capability of Individually Carried Bureau of Mines Rescue Breathing Apparatus in Sub-Freezing Temperatures
Investigators:	Richard L. Burse, Sc.D., Lewis H. Strong, Ph.D. and Leander A. Stroschien

Background:

The US Army Research Institute of Environmental Medicine was requested by the Bureau of Mines (BuMines) of the US Department of the Interior to determine the cold weather capability of their rescue breathing apparatus (RBA). BuMines needed to know the lowest ambient air temperature between 0 and -30° C at which each of the three different models of currently certified RBA could be used by human volunteers at rest and while performing light to moderate work (oxygen consumptions ranging from 0.3 to 2.0 $l \cdot min^{-1}$). The RBAs are of closed circuit design, which means that the breathing gas mixture continuously recirculates. The CO_2 produced by metabolism is removed by a chemical scrubber and the O_2 consumed by the user is replaced from a small rechargeable gas cylinder. The CO_2 scrubber, oxygen bottle, gas expansion chamber and metering devices are all mounted on a frame which is worn like a back pack. The inspired breathing gas is supplied to the user by a hose connected to a full face mask with a single large lens for vision and is returned to the backpack by another hose. Since the exhaled breathing gas contains moisture which is not removed during the recirculation process, the RBAs are susceptible to freezing up at temperatures below 0° C. The three RBAs tested were all certified for use in US mining operations at temperatures down to 0° C, but none had been previously tested by humans at lower temperatures. Although designed to provide information to the BuMines, this study benefited the Army in two ways. First, the closed circuit RBA now certified by BuMines for rescue work in mines are the same devices available for procurement by the US Armed Forces; these devices require testing to determine their operational capability for use in military operations in cold weather. Second, scientists at this Institute gained knowledge of the procedures, techniques and instrumentation needed for cold weather testing of closed circuit breathing devices and of the parameters of RBA function under cold weather conditions. The latter knowledge is directly applicable to design guidance for military breathing devices for use under a variety of environmental conditions.

Progress:

Two samples of each of the three different RBAs currently certified by BuMines were obtained for test. Two of these, the Scott and Drager-National, have nominal operation times of 4 hours and are currently in production. The other, the McCaa, has a nominal operation time of only 2 hours and is no longer in production, but is still widely used in the mining industry, spare parts being obtained by cannibalization. By agreement with BuMines, RBAs were considered operational in sub-freezing temperatures if they operated for at least one-half of their nominal operation times.

Six young male volunteers were each trained on and assigned to a single RBA unit for the entire period of testing; two other volunteers were trained on all 3 RBA types and filled in occasionally when the principal subjects were ill or administratively unavailable. Thus, each principal subject was thoroughly familiar with the operation of his RBA. This maximized the likelihood that malfunctions of the RBA were due to environmental conditions rather than to improper operations.

Operational testing was divided into two phases. Phase I tested the performance after overnight storage of the RBA at the testing temperature (cold soaking). Phase II tested the performance after overnight storage at + 15° C. All of Phase I testing was completed before Phase II began; tests successfully passed in Phase I were not repeated in Phase II. The sequential testing design is shown in Figure 1. The initial Phase I temperature was -20°C. The RBAs that passed that test were then tested at colder temperatures, while those that failed the initial test were tested at warmer temperatures.

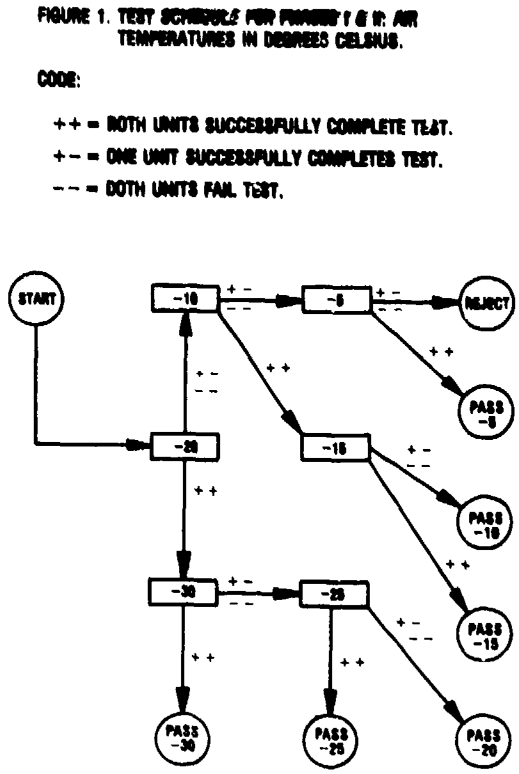

Figure 1. Test schedule for Phases I and II: air temperatures in degrees Celsius.

Tests were conducted in a large climate-controlled chamber at the specified temperature $\pm$ 0.5° C with air motion 60-80 m•s^{-1}. After connection to the measuring instrument cables, subjects performed a 40 minute cycle of treadmill work and rest: 20 minute slow walk ($\dot{V}O_2$ = 1.1 $\pm$ 0.1 l•min^{-1}), 10 minute fast walk ($\dot{V}O_2$ = 2.0 $\pm$ 0.2 l•min^{-1}) and 10 minute rest, repeated until RBA failure occurred or one-half the nominal operation time was attained.

Subjects' rectal and 11-point skin temperatures were continuously monitored for safety along with the following RBA parameters: temperature at 6 points within the breathing circuit, maximum inspiratory and expiratory pressures within the face mask, O_2 and CO_2 concentrations in inspired air and O_2 cylinder pressure. Subjective ratings of respiratory effort, body thermal sensation and comfort were also obtained. Leaking of the seal between the user and the face mask was tested during each rest period by inserting the head into a series of 3 boxes of ~1 m^3 volume. One box of the 3 contained a nearly saturated concentration of isoamyl acetate (banana oil), which was readily detected under control conditions if a finger was thrust through the mask seal. During the environmental tests, no mask leakage was ever detected, indicating good seals on all 3 types of RBAs at all temperatures.

Following each test, RBAs were washed, rinsed with disinfectant, rinsed with alcohol and dried inside and out with warm air from hair dryers. This was necessary to prevent any residual moisture in or on the instrument parts from freezing and causing malfunctions prior to testing. Preliminary testing showed that the RBAs would not work properly under freezing conditions unless they were bone-dry at the start of each test.

Table 1 shows the physical characteristics of the test subjects. All were representative of body builds found in the Army; none was extreme in any regard.

TABLE 1

Physical characteristics of test subjects

RBA type	Age (yr)	Height (cm)	Weight (kg)	Body surface area (m^2)	Body fat (%)
D	19	179.4	74.7	1.93	20
	22	169.9	64.9	1.75	17
M	35	175.6	74.1	1.90	19
	23	170.5	66.5	1.77	16
S	22	177.0	83.6	2.01	19
	23	173.7	75.6	1.90	18
Alternate	22	175.7	74.6	1.90	15
	21	178.5	71.5	1.89	15

Table 2 shows the operating times in Phase I (after overnight cold-soaking). The Scott units performed the best, operating for 2.3 - 3.3 hours at -20° C. The Drager-National and McCaa units each operated for at least half their nominal times at -10° C, but not at colder temperatures.

TABLE 2

Endurance time and condition of each RBA at end of low temperature operational tests. Phase I: overnight storage at temperature of subsequent operational test

Test temperature (°C)	RBA unit no.	Endurance time (min)	Pass/ Fail test	Condition at end of test
-10	D-1	160	P	operational
	D-2	160	P	operational
	M-1	75	P	CO_2 too high
	M-2	67	P	CO_2 too high
-15	D-1	12	F	CO_2 too high
	D-2	10	F	CO_2 too high
	M-1	30	F	CO_2 too high
	M-2	28	F	CO_2 too high
-20	D-1	4	F	CO_2 too high
	D-2	0	F	CO_2 too high
	M-1	23	F	CO_2 too high
	M-2	27	F	CO_2 too high
	S-1	200	P	operational
	S-2	141	P	out of O_2
-25	S-1	70	F	out of O_2
	S-2	190	P	operational
-30	S-1	80	F	out of O_2
	S-2	(improper test, not repeated)		

Failure modes were quite different for the 3 instruments. The Scott units did not operate properly at -25° C or below because the pressure in the cold-soaked O_2 bottle was reduced below that needed to properly activate the O_2 dispensing mechanism and alarm unit. As a result, when the Scott unit was first turned on, the O_2 pressure alarm signal valve opened properly, but did not shut off immediately as it should have. This vented an undetermined amount of O_2 from the cylinder which reduced the supply below that needed for half normal operation times. This problem occurred with both Scott units and appeared to be inherent in the design.

The Drager-National and McCaa units failed because they did not properly scrub CO_2 from the breathing circuit at -15° C and below. The Drager-National units failed to properly scrub CO_2 from the start of each test when cold-soaked. However, if the scrubber could stumble along for 45 to 60 minutes without allowing the inspired CO_2 concentration to exceed the cut-off values (4% at any time, 3% for no more than 2 minutes or 2% for no more than 10 minutes), it would warm up enough to continue functioning properly until the O_2 supply ran out. On the other hand, the function of the McCaa unit scrubber deteriorated progressively from the start of each test at temperatures of -15° C and below. This permitted CO_2 to build up to excessive levels, particularly during the fast walk portion of the work-rest cycle. The colder the temperature, the faster the build-up.

Table 3 shows the operating times in Phase II (after overnight storage at +15° C). Again the Scott units performed the best, operating for 3.0 - 3.5 hours at -25° C. At -30° C, one unit had excessive breathing resistance after 71 minutes, although the cylinder pressure was still 450 psi, a bit less than one-third full. The cause of the malfunction could not be determined. On a re-test, ice built up in the expired air line. However, the other Scott unit performed properly for 120 minutes.

The Drager-National and McCaa units both operated for one-half nominal time at -20° C. At both -20 and -25° C one Drager unit progressively iced up until breathing effort became intolerable at 134 and 102 minutes, respectively, but the other unit remained operational for more than 120 minutes both times. The McCaa units always failed because of progressive build-up of CO_2 to excessive levels. At -20° C, both units passed the test by 4 and 8 minutes, which leaves little margin for error. At -15° C, both units performed successfully for 68 minutes, whereupon one unit exceeded the CO_2 criteria. This temperature thus appears to be a safer lower limit, but not by much.

TABLE 3

Endurance time and condition of each RBA at end of low temperature operational tests. Phase II: overnight storage at +20°C

Test temperature (°C)	RBA unit no.	Endurance time (min)	Pass/ Fail test	Condition at end of test
-15	M-1	68	P	CO_2 too high
	M-2	98	P	operational
-20	D-1	136	P	operational
	D-2	134	P	excessive breathing resistance
	M-1	68	P	CO_2 too high
	M-2	64	P	CO_2 too high
-25	D-1	120	P	operational
	D-2	102	F	excessive breathing resistance
	S-1	187	P	out of O_2
	S-2	211	P	operational
-30	D-1	93	F	out of O_2
	D-2	160	P	CO_2 too high
	S-1	120	P	operational
	S-2	71	F	excessive breathing resistance
	S-2 (repeat)	101	F	excessive breathing resistance

The coldest temperatures for proper operation under each storage condition are summarized in Table 4. The Scott is clearly the instrument of choice, because of its ability to properly scrub CO_2 at all temperatures tested. Neither the Drager-National nor the McCaa are well-suited for cold weather use. Their malfunctions are insidious, as subjects will not necessarily be aware of the build-up of CO_2 until after the recommended upper limit of 5% has been exceeded. For this reason, their use by military personnel is not recommended.

TABLE 4

Coldest temperature for proper operation of RBA's for one-half certified duration. Storage conditions: cold = overnight storage at temperature of subsequent tests, warm = overnight storage at +20°C

RBA type	One-half certified duration (min)	Storage condition	Coldest operating temperature (°C)	Measured operating time (min)
D	120	cold	-10	160
		warm	-20	134
M	60	cold	-10	67
		warm	-15	68
S	120	cold	-20	141
		warm	-25	187

Respiratory pressures within the face mask generally ranged from ±5 cm H_2O at rest to ±10 cm H_2O during the fast walk. Maximum inspiratory pressures normally were within 2-3 cm H_2O of maximum expiratory pressures. When either of the respiratory pressures exceeded 15 cm H_2O, subjects complained of difficulty breathing and very soon refused to continue the test. These high pressures were caused by frost accumulation within the breathing hoses to the mask.

During the fast walk, average pressures were 6-7, 9-10 and 13-14 cm H_2O for the Drager, Scott and McCaa units, respectively. Face mask pressures correlated only with the work rate and not with CO_2 or O_2 concentrations, or breathing circuit temperatures.

The results of the study will be reported in a BuMines Technical Report "Low Temperature Testing of Rescue Breathing Apparatus" under the terms of the working fund agreement. A draft of the manuscript has been prepared and is in the final stages of typing. The results will also be reported in the scientific literature for use by practitioners in the areas of Industrial Hygiene and Environmental Protection. These reports will complete the project.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Hard Work for Walking on Snow of Various Depths
Investigators:	Kent B. Pandolf, Ph.D., Fred R. Winsmann and Ralph F. Goldman, Ph.D.

Background:

In a previous study, the metabolic energy expenditure and terrain coefficients for walking on snow were determined using 6 male volunteer subjects. These subjects each walked for 15 minutes at each of two fix-paced speeds, 0.67 and 1.12 $m \cdot s^{-1}$ (1.5 and 2.5 mph), on a treadmill (level) and on a variety of snow depths. Energy expenditure increased linearly with increasing depth of footprint depression, reaching a ratio of about 5:1 when a 45 cm footprint depression was compared to 0 cm depression. Although these subjects were considered above average in terms of physical fitness (mean $\dot{V}O_2$ max = 51.4 $ml \cdot kg^{-1} \cdot min^{-1}$), all failed to complete the 15 minute walk because of exhaustion (at about 7.5 minutes) at an average footprint depth of 35.0 cm at a walking speed of 1.12 $m \cdot s^{-1}$. Practical limits for snow walking without snowshoes not exceeding about 50% $\dot{V}O_2$ max were developed, with 20 cm being the maximal depth at 0.67 $m \cdot s^{-1}$ and 10 cm at 1.12 $m \cdot s^{-1}$ (3).

Certainly, walking on snow is a very tiresome form of human locomotion (1-3). However, little is known about the self-paced work rates soldiers would adopt as "hard work" for prolonged snow walking.

Progress:

This study was developed to provide information about (a) the measured steady-state energy expenditure for self-paced snow walking at various snow footprint depths and (b) the effect of load carrying (backpack) on self-pacing at various snow depths.

Six healthy male volunteers, each less than 30 years of age, from the Institute staff or NLABS test subject pool will first have a determination of their maximal oxygen uptake performed on a treadmill in the laboratory. They will walk at 1.56 $m \cdot s^{-1}$ (3.5 mph) on a level treadmill; the grade will be increased by 2.5% every two minutes, heart rate will be monitored continuously. At and above a heart rate of 160 $beats \cdot min^{-1}$ expired air samples will be obtained during the last minute of each grade elevation. A plateau in calculated oxygen uptake (sample differences of less than 150 $ml \cdot min^{-1}$ or 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$) increase will determine the maximum $\dot{V}O_2$ (analysis and calculation will be completed before each successive grade increment is instituted).

In the second part of the study, the subjects will each walk a mile outdoors in 3-5 different depths of snow (up to approximately 50 cm deep). Subjects will walk at a self-determined voluntarily "hard" pace which they are able to sustain for 2-4 hours under each of three load conditions in field clothing and combat boots, but without backpack; with a 10 kg backpack; and with a 20 kg backpack. At each quarter mile, expired gas samples will be collected in a Max Planck gasometer for four minutes; these will be analyzed for oxygen and the results used to determine energy expenditure. Heart rate will be determined by radial pulse count, for 30 seconds after each quarter-mile walk. After each walk, the temperature, wind velocity, snow-water content, and the depth of footprint depression in the snow will be measured. Techniques and calculations will be as reported by Pandolf et al. (3).

Unfortunately, insufficient snowfall and cover in this area prevented our Division from conducting this study during the winter and early spring months of FY80. Hopefully, in FY81 it will be possible to go TDY to either Vermont or New Hampshire in order to conduct a field study to accomplish the research needs of this project, in addition to establishing and possibly using the snow course at NLABS. These options seem mandatory considering the unpredictability of weather conditions and snow cover in this area.

Presentations:

1. Goldman, R. F., M. F. Haisman and K. B. Pandolf. Metabolic energy cost and terrain coefficients of walking on snow. Paper delivered at the Third International Symposium on Circumpolar Health, Yellowknife, Northwest Territory, (Cda) July 8-11, 1974.

2. Pandolf, K. B., F. R. Winsmann, M. F. Haisman, and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. The Physiologist 17:301, 1974.

Publication:

Pandolf, K. B., M. F. Haisman, and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. Ergonomics 19:683-690, 1976.

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3. Pandolf, K. B., M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. Ergonomics 19:683-690, 1976.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Predictive Modeling of Man Undergoing Whole Body Immersion Cooling With and Without Protective Clothing
Investigators:	Hylar L. Friedman, CPT, M.D., Louis H. Strong, Ph.D., Gaither D. Bynum, M.D., Gin K. Gee, James A. Bogart and Ralph F. Goldman, Ph.D.

Background:

This Institute has long been involved in the evaluation of clothing for its insulative properties in air and while immersed in water. In the past, various types of wet suits have been evaluated by copper manikin studies; insulation values for 1/4" vinyl, 3/8" polyurethene, and 1/4" neoprene suits have been found to be 0.43 clo, 0.61 clo, and 0.76 clo, respectively. Several studies have been carried out on nude men totally immersed in water at temperatures ranging from 20°C to 35°C, and other studies were performed in 20° C to 28° C water, both on nude men and men wearing the aforementioned wet suits. Data collected in these studies included changes in rectal and mean weighted skin temperature with time, and in some studies, metabolic rates and heat flow measurements.

Progress:

Two models have been developed for the prediction of mean weighted skin temperature during cold water immersion. Factors considered include body mass, body fat, height, peripheral insulation, central conductance, initial skin and rectal temperatures.

The mathematical form of this first modelling approach (Model I) is:

$$T_{s(t)} = Ae^{-bt} + Ce^{-dt} + T_w$$

where $T_{s(t)}$ = skin temperature as a function of time

T_w = water temperature in degrees Kelvin

A,C,b, and d are constants; for this first attempt, these are individualized for each subject and condition.

By utilizing the T_s (60 minutes), the end point of each experiment, it was possible to construct a formula to predict the difference between $T_{s(t)}$ and T_w at 60 minutes. Values for b and d were optimized in terms of the parameters outlined above. A and C then were fixed by solving the boundary conditions of the experiment, with initial skin temperature $T_{s(o)}$, and T_w, and the equation for 60 minutes

$$(1)\quad T_{s(o)} = A + C + T_w$$

$$(2)\quad T_s\ (60) = Ae^{-60b} + Ce^{-60d} + T_w.$$

Model II is similar to the concentric shell model of Stolwijk (1) and considers the heat transfer through N contiguous compartments (N arbitrarily large) including the body core, a fat layer, a skin layer and any external thermal protective layers (I_{ext}). The net energy density stored in the ith compartment is given by the heat transport equation to be

$$P_i\, C_{vi} = \frac{dTi}{dt} = a_{ij}(T_i - T_j) + Q_i\,(t)$$

where we have ignored the energy flux through the thermal gradient within each compartment. P_i and C_{vi} are respectively the mass density and specific heats of the ith compartment. The a_{ij} are heat transfer coefficients which describe the heat flux from compartment i to compartment j. Their reciprocals are the thermal resistances. The Q_i represent active sources or sinks of thermal energy operative in this compartment and may include metabolic heat production, an externally applied heating source, or heat directly applied to the skin through the cutaneous blood supply.

The general solution to the system of N coupled differential equations has been obtained in closed form for N temperature profiles, T_i, subject to an arbitrary set of boundary conditions. The system has also been solved in reverse for $Q_i(t)$ in terms of an arbitrary temperature profile T_i.

A computer program was used to simulate the time development of mean weighted skin and rectal temperatures of six nude, male subjects having body fats ranging from 10 to 25%, and immersed in water at 20 and 28°C. The heat transfer coefficients from core to fat, and from fat to skin were determined by successful stimulations of the time variations of experimental temperatures using the measured metabolic rates. These heat transfer coefficients, which differed from subject to subject by as much as a factor of 2.5, were found to be inversely proportional to the compartment surface area. These coefficients were successfully used to predict skin and rectal temperatures for the same set of subjects in protective clothing.

Currently, two technical reports are nearly completed which will define the two different models (Model I and Model II) concerning the prediction of mean weighted skin temperature during cold water immersion as described above. Further validation for both models would appear necessary. For Model I improvements in the validity at water temperature below 20°C will improve its predictability. This model intentionally ignores metabolic rate, exercise and shivering. The authors feel a person at risk for prolonged cold water immersion, in such cases as after a boat capsizes or after an individual bails out from a plane should have a life vest and should be informed enough to remain as still as possible in the water. Theoretically, this model can accommodate subject or water motion by changing the I_{ext} value for the individual to account for the effect of forced convection. Further applications of this model may include partial immersion, where one must calculate mean weighted external insulation in water and air, as well as cold air cooling, where one must use dry clothing insulation values. However, it also seems clear that less empiric, more rational models should allow greater progress to be made in predicting core (T_{re}) as well as skin temperature responses. For Model II a wider distribution of percent body fat will improve its applicability.

Presentation:

Goldman, R. F., H. Friedman, G. Gee, G. Bynum, J. Bogart, C. Levell, and L. H. Strong. Metabolic versus vaso-constrictive response to cold water immersion. The Physiologist 22:46, 1979.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Evaluation of Fitness Reference Standards of Body Composition
Investigators:	Nancy A. Pimental, Richard L. Burse, Sc.D., Ralph F. Goldman, Ph.D. and Kent B. Pandolf, Ph.D.

Background:

Current Army Regulations (AR 600-9) discuss the relationships between height, weight, military appearance and physical fitness of the soldier (1). Those individuals who do not meet stated weight standards (after goals have been established but not met) could receive unfavorable evaluation reports, unfavorable remarks in their official military personnel file, or receive a bar to re-enlistment, or may even be discharged from the Army. While the use of such height-weight tables is often sufficient, for some individuals the use of weight alone as an indicator of fitness may be misleading. These individuals include those who have a very high muscle mass or those who are fit but who have large uniquely located fat deposits which are genetically determined. It might be unrealistic, indeed in some cases physically hazardous, to expect weight losses as indicated by AR 600-9 in these soldiers.

It is therefore desirable to use an alternative method to evaluate fitness and establish weight goals for the soldier. Such a method should give information as to the body composition of the subject in order to separate the above described individuals from the merely overweight. This can be done easily by the use of skinfold assessment of total body fat content.

The purpose of this ongoing study is to measure initial amounts of body fat and monitor changes in body fat in those soldiers who do not meet current Army weight goals. Collected data is given to the Medical Officer for use in prescribing diet and/or exercise programs.

Progress:

During FY 80 the Medical Officer at NLABS referred one military person for skinfold assessment. The individual (age 36) was being reassessed after having been on a diet/exercise program, this being his fourth evaluation. Skinfolds were taken at four sites: subscapular, triceps, biceps and suprailiac. The method of Durnin and Womersley was used to calculate % body fat (2). Weight was measured with a balance scale. Data is presented on this individual in Table 1. Table 2 shows mean fat content, classified according to age and sex, from a study by Durnin and Womersley (2).

TABLE 1

Follow-up evaluation (2 yrs) of body composition of 36-year old male individual.

Date	Weight (lbs)	% Fat	Lean Body Mass (LBM)	Weight Limit (AR 600-9)	LBM plus Mean % fat
Mar 78	232	28.4	166	197	216
Jun 78	229	30.6	159	197	206
Sep 78	229	28.8	163	197	212
Feb 80	197	22.9	152	197	197

TABLE 2

Mean % fat according to age and sex.

Sex	Age	%Fat
Male	17-19	15
	20-29	15
	30-39	23
	40-49	25
	50-72	28
Female	16-19	26
	20-29	29
	30-39	33
	40-49	35
	50-68	39

Using lean body mass plus a mean % body fat (obtained from Table 2) as the criteria for a reasonable weight, it appears that this individual has reached his weight goal on his most recent evaluation. Future work will include continuing to monitor this individual as well as taking initial measurements on referred military personnel.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Additive Effects of Solar and Metabolic Heat Load in Predicting Heat Intolerance
Investigators:	Kent B. Pandolf, Ph.D., Yair Shapiro, M.D., Baruch Givoni, Ph.D., Fred R. Winsmann, John R. Breckenridge and Ralph F. Goldman, Ph.D.

Background:

The solar radiant environment, as a function of the particular geographic region, hazy or clear sky, cloud cover, terrain cover and albedo, time of day and solar elevation, is an important consideration for military operations in hot environments. This Division has developed methods of prediction for the actual solar heat load arriving at the skin in lightly clothed men (1) and more heavily clothed men (2). However, these studies have been of a theoretical physical nature, validated by direct measurement on heated, sweating copper manikins.

Although we have been able to develop the ability to predict rectal temperature and heart rate responses to work, environment and clothing (3,4), further refinement of our predictive capabilities is seen to be necessary. This study evaluated the decrement in tolerance time or performance to work, rest in the heat as effected by a simulated ambient solar heat load. The results of these experiments should provide adequate data for integrating the metabolic responses of solar and metabolic heat and enable us to predict more accurately the soldier's responses to operational combat clothing and equipment during actual field situations in hot environments.

We have completed the first in a series of experiments involving the effects of solar radiant environment on soldier's performance to work or rest in the heat. Initially, 24 subjects were acclimatized to heat walking in shorts at $1.34\ m \cdot s^{-1}$ for two 50-minute periods separated by 10-minutes rest at $49^{\circ}C$, 20% RH. After six days of acclimatization, the 24 subjects were divided into three groups of eight for experimental evaluations during either rest, walking at $1.34\ m \cdot s^{-1}$, or walking $1.34\ m \cdot s^{-1}$ at a 5% grade. A bank of 72 infrared 350 watt lamps were secured at near ceiling height in the NLABS Tropical Environmental Chamber. This bank of lights simulated approximately 90% of a typical, severe solar heat load. Subjects were evaluated during rest or walking ($1.34\ m \cdot s^{-1}$, 0 or 5% grade), at 40^{o} C, 32% RH and 35^{o} C, 75% RH with and without the solar radiant load while wearing either shorts, socks and sneakers or the combat tropical uniform. The proposed experimental duration was a total of two hours (10 minute rest, 50 minute work, 10 minute rest, 50 minute work). During these experiments water was administered ad libitum while air motion was constant at approximately $0.5\ m \cdot s^{-1}$.

Progress:

An extensive statistical and quantitative analysis of these experimental findings concerning solar heat load (Q_s) has been completed which involved a variety of physiological measurements. These physiological measurements included heart rate (HR), rectal temperature (T_{re}), sweat rate ($\dot{m}_{sw}$) and energy expenditure (M). In nearly all statistical contrasts of final test values, Q_s resulted in higher ($P < 0.01$) physiological responses (range of mean differences: HR, 14-42 $beats \cdot min^{-1}$; T_{re}, 0.45 - 1.48^{o} C; $\dot{m}_{sw}$, 218-314 $g \cdot m^{-2} \cdot h^{-1}$) as compared to no Q_s during rest or work. At similar levels of WBGT (~33.5^{o} C), responses to Q_s (40^{o}C, 32% RH) were similar to no Q_s (49^{o}C, 20% RH) dressed in shorts (walking, $1.34\ m \cdot s^{-1}$ at 5% grade) and tropical uniform (walking $1.34\ m \cdot s^{-1}$). While HR and M did not differ statistically with Q_s, the $\dot{m}_{sw}$ (both uniforms) and T_{re} (shorts only) were statistically significant ($P < 0.05$) with respect to Q_s. These findings illustrate the importance of considering the solar heat load components in the heat balance equation for outdoor environments. The marked increase in rectal temperature with the simulated heat load in both clothing systems and environmental conditions during rest or work is quite apparent as illustrated in Figure 1. More recently, our Division has collaborated with a visiting scientist from Israel (Dr. Baruch Givoni) concerning the development of prediction equations relative to rectal temperature and heart rate as influenced by solar heat load. A preliminary equation developed to predict the impact of solar heat load on rectal temperature is as follows:

$$T_{re(f)} = 36.75 + 0.004(M-W_{ex}) + 0.0011H_{(c)} + 0.0025H_{(r)} + 0.8\,e^{\,0.0047\,(E_{req} - E_{max})}$$

where: $E_{req} = H_c + H_r + (M-W_{ex})$

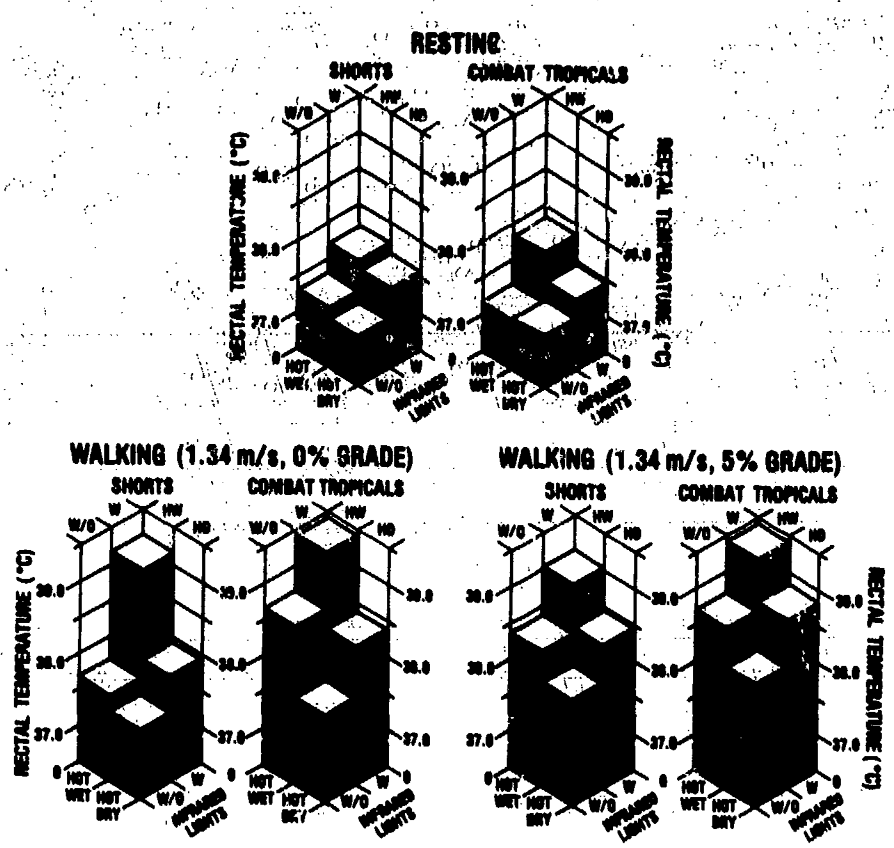

Figure 1. Rectal temperature responses for our subjects during rest and work wearing either shorts or combat tropical uniforms in hot/wet or hot/dry environments with (W) and without (W/O) simulated solar heat load (infrared lights).

As part of this same study, but for validative purposes, other individual blocks of experimentation will be conducted in the future. The first series of experiments to be conducted during the winter or early spring months of FY81 will evaluate the physiological responses of two different radiant heat loads, three different wind speeds and three different clothing ensembles at 40°C, 20% RH in 10 male soldiers prior to heat acclimatization. Half of these soldiers will be acclimated to heat with a solar radiant load while the other half will be acclimated to heat without solar load. All subjects will be re-exposed to all of the environmental conditions outlined above.

Presentation:

Pandolf, K. B., Y. Shapiro, J. R. Breckenridge, and R. F. Goldman. Effects of solar heat load on physical performance at rest and work in the heat. Fed. Proc. 38:1052, 1979.

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4. Givoni, B. and R. F. Goldman. Predicting heart rate response to work, environment and clothing. J. Appl. Physiol. 34:201-204, 1973.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Role of Dehydration in Limiting Human Performance While Working in the Heat
Investigators:	Kent B. Pandolf, Ph.D., Baruch Givoni, Ph.D. and Ralph F. Goldman, Ph.D.

Background:

Approximately three years ago an investigation was conducted to study the acute phase of dehydration which is more characteristic of a military operation in hot environments. Predictive modeling of the effects of dehydration for important physiological performance parameters, such as rectal temperature (T_{re}) and heart rate (HR) was, to our knowledge, nonexistent. Thus, the purpose of this investigation was to derive predictive formulas for rectal temperature and heart rate considering human performance of exercise in the heat.

Progress:

The technique for induction of dehydration was to define a characteristic morning weight for each of the 16 subjects by weighing over a period of four or five days before the start of the study. This established a "baseline" weight for each individual subject. Subjects were then brought into the laboratory and acclimated by walking in the heat at 1.34 $m \cdot s^{-1}$ for two 50-minute periods separated by a 10 minute rest at 49°C, 20% RH.. State of hydration was altered by having the subjects report to the Climatic Chamber at 2200 hours each evening and "rest" at 49°C 20% RH while withholding, allowing or encouraging water intake until the desired target dehydration was approached. At approximately 0300 hours each morning, subjects were weighed and transferred to a comfortable room to sleep. At 0700 hours all men were weighed, state of dehydration estimated, and given a light standard breakfast with fluid adjustment appropriate to the target dehydration individually attempted.

Target hydration levels of 0, -3 and -5% of baseline were evaluated during rest or walking at 1.34 $m \cdot s^{-1}$, 0 and 5% grade, at 54°C, 10% RH; 49°C, 20% RH; 35°C, 24% RH, 48°C, 72% RH and 25°C, 84% RH. Exposure time totaled 110 minutes while exercise involved two 50-minute walking periods with a 10 minute intervening rest. Rectal temperature and mean weighted skin temperature were recorded continuously and HR checked periodically. The individual level of dehydration was maintained throughout the exposure by administration of water in amounts determined from the acclimatization days as adequate to maintain body hydration at the initial level. Subjects were studied only two days per week, allowing 48 hours between exposures for full recovery of hydration and restful sleep. Thus, we evaluated three levels of metabolic rate, a wider variety of air temperatures and levels of humidity at three levels of hydration.

From the analysis of the experimental data described above, it was possible to express the effect of dehydration as proportional to the final elevation in the rectal temperature of hydrated individuals exposed to similar environments and work levels. The effects of the level of dehydration on rectal temperature are a faster rate of elevation and, therefore, a higher final level where the duration of exposure was limited; however, the final equilibrium temperature, if established, appears to be no higher than without dehydration at these levels. Formulas previously published for predicting rectal temperature (1) were modified using an exponent containing both a dimensionless constant and the level of dehydration in percent. Previously published predictive formulas for HR (2) were also modified to include a dimensionless constant which considered percent dehydration.

During rest, dehydration was found not to alter T_{re}. Predictive formulas (modified from J. Appl. Physiol. 32:812, 1972) at any time (t) and final T_{re} (T_{ref})and the time pattern of change during work (T_{rew}) and recovery (T_{rer}) are:

$$T_{ref} = 36.75 + 0.004(M - W_{ex}) + (0.0128\ clo^{-1})(T_a - 36) + (0.8e^{0.0047(E_{req} - E_{max})}\ e^{0.01D}$$

$$\text{Work:}\quad T_{ref} = T_{reo} + (T_{ref} - T_{reo})\ 1 - e^{-k}\,(t - t_d)(1 + 0.1D)$$

$$\text{Rec:}\quad T_{ret} = T_{rew} - (T_{rew} - T_{rer})\ 1 - e^{-}\ (t - t_{drec})\ e^{-0.07D}$$

where: D = % dehydration; op cit for other terms. A preliminary formula, which predicts heart rate considering dehydration is:

$$I_{HR_{(Dehyd)}} = 25 + (I_{HR} - 25)(1 + 0.06D)$$

Using this I_{HR} for dehydration, final HR, and HR at time t, are computed as previously published (J. Appl. Physiol. 34:201, 1973).

This predictive capacity to consider state of hydration has been tentatively added to our model which predicts military performance capacity and the occurrence of heat stress and/or heat casualties during military operations.

The tentative coefficients developed from these experiments resulted in only a minor adjustment to the original predictive formulas. However, these coefficients were derived from only one group of test subjects and somewhat limited work and environmental conditions. An entirely different group of test subjects need to be evaluated to validate the coefficients derived from previous dehydration experiments. The validation study will involve 8-16 acclimatized subjects, three levels of dehydration (0,3,5%), two levels of physical work (300 and 500 watts) and two environmental conditions (35^{o},45^{o}C). We also plan to compare physiological responses of men and women to dehydration both before and after being heat acclimatized.

While no additional data was collected during FY80, Dr. Baruch Givoni, (visiting scientist, Ben Gurion University of the Negev, Israel) has suggested further refinements concerning the coefficients for prediction equations pertaining to state of hydration and also some further potential validating studies. Hopefully, these validation studies will be conducted during FY81.

Presentations:

1. Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule, and R. F. Goldman. Effects of dehydration on predicted rectal temperature and heart rate during work in the heat. Med. Sci. Sports 9:51-52, 1977.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Sex Differences in Heat Tolerance and Acclimatization
Investigators:	Yair Shapiro, M.D., Barbara A. Avellini, Ph.D., Nancy A. Pimental and Kent B. Pandolf, Ph.D.

Background:

The reactions of men to changes in environmental temperature have served as the basis for our understanding of human heat tolerance and thermoregulation. There appears to be less certainty about the thermoregulatory patterns of women, however. Physiological responses to heat stress may be expected to differ in men and women due to several possible factors, including the lower cardiorespiratory fitness (1), the higher body fat content (2), the lower body weight (3), and the lower skin surface area and the higher surface area-to-mass ratio (A_D/wt) (4) of women compared to men. In addition, the fluctuating hormonal levels of estrogen and progesterone accompanying the menstrual cycle may also influence women's tolerance to heat stress.

Several studies have shown that women thermoregulate less effectively than men when exposed to an acute heat stress (5). Under the same heat load, core temperature and heart rates were higher and sweat rates were substantially lower in women (6). However, when the cardiorespiratory fitness of the men and women was considered, physically fit women were found to have similar (1) or even lower core temperatures and heart rates than fit men during an acute heat exposure despite their lower rates of sweating. Although heat acclimatization served to eliminate many of the sex-related physiological differences, sweat rates still remained lower for women (6).

One of the sources for the controversy in the literature regarding apparent sex-related thermoregulatory differences may result from the environmental conditions under which the experiment was conducted.

The purpose of this study was to define the possible physiological differences between the sexes for humid and dry heat, and to suggest the thermoregulatory mechanisms involved.

Progress:

Nine female and 10 male heat acclimatized volunteer soldiers served as subjects. The subjects were exposed to a comfortable climate (20°C, 40% RH), mild-wet weather (32°C, 80% RH), two hot-wet conditions (35°C, 90% RH; 37°C, 80% RH) and two hot-dry conditions (49°C, 20% RH; 54°C, 10% RH). Exposures lasted 120 minutes: 10' rest, 50' walk ($1.34\ m \cdot s^{-1}$), 10' rest, 50' walk. During hot-dry exposures, heart rate (HR) and rectal temperature (T_{re}) were significantly lower for males than females by 13 and 20 $beats \cdot min^{-1}$ and by 0.25 and 0.32°C for the two conditions (Figure 1); no significant differences in sweat loss ($\dot{m}_{sw}$) were observed. During hot-wet exposures, both mean final T_{re} and $\dot{m}_{sw}$ were lower in females than males by 0.34 and 0.24° C and by 106 and 159 $g \cdot m^{-2} \cdot h^{-1}$, respectively (Figure 2) (males sweated 25 and 40% more than females). None of these differences correlated with maximal oxygen uptake, body weight, skin surface area or percentage of body fat. During hot-wet exposures, a negative relationship between surface area-to-mass ratio (A_D /wt) and T_{re}, mean skin temperature, HR and change in heat storage was found (Table 1). It was suggested that three major factors are involved in these differences: (a) higher A_D/wt for females than for males, (b) better sweat suppression from skin wettedness for women and (c) higher thermoregulatory set point for women than for men. It can be concluded that females and males react in a physiologically similar manner under comfortable environmental conditions; females tolerate hot-wet climates better than males, and males better tolerate hot-dry conditions.

Prior to the above experiments, all subjects were heat acclimatized to 49° C, 20% RH for 6 consecutive days. These exposures also lasted 120 minutes: 10' rest, 50' walk ($1.34\ m \cdot s^{-1}$), 10' rest, 50' walk. It was concluded that males and females acclimate to a hot-dry environment at the same rate. In spite of similar rates of achieving heat acclimation, the final T_{re} and mean skin temperature remained higher for the females after acclimation as well as before acclimation. It was suggested that these differences are mainly due to a higher thermoregulatory setpoint for the females. The pre-acclimation sex differences in heat balance and heat transfer (lower R + C, E_{sw} and $(T_{re} - \bar{T}_{sk})$ for the women) were not altered by the acclimation process.

Finally, these same heat-acclimated men and women were exposed to these same hot-dry conditions (49°C, 20% RH) for 4 hours to determine the effect of prolonged work in the heat on physiological differences between the sexes. Hourly exposures consisted of 10' resting and 50' walking at 1.34 $m \cdot s^{-1}$. It was concluded that prolonged exposure does not enhance any sex-related physiological differences in response to dry heat exposure. Women can maintain sufficiently high sweat rates over four hours to reach and maintain thermoequilibrium. The apparently higher cardiovascular strain of women throughout the heat exposure, as evidenced by their higher HR, can be attributed to the relatively higher thermal stress under which they worked at the same absolute workload. In addition, it appears that an acclimation procedure of two hours per day for six days does not fully acclimate an individual for longer periods of work in the heat.

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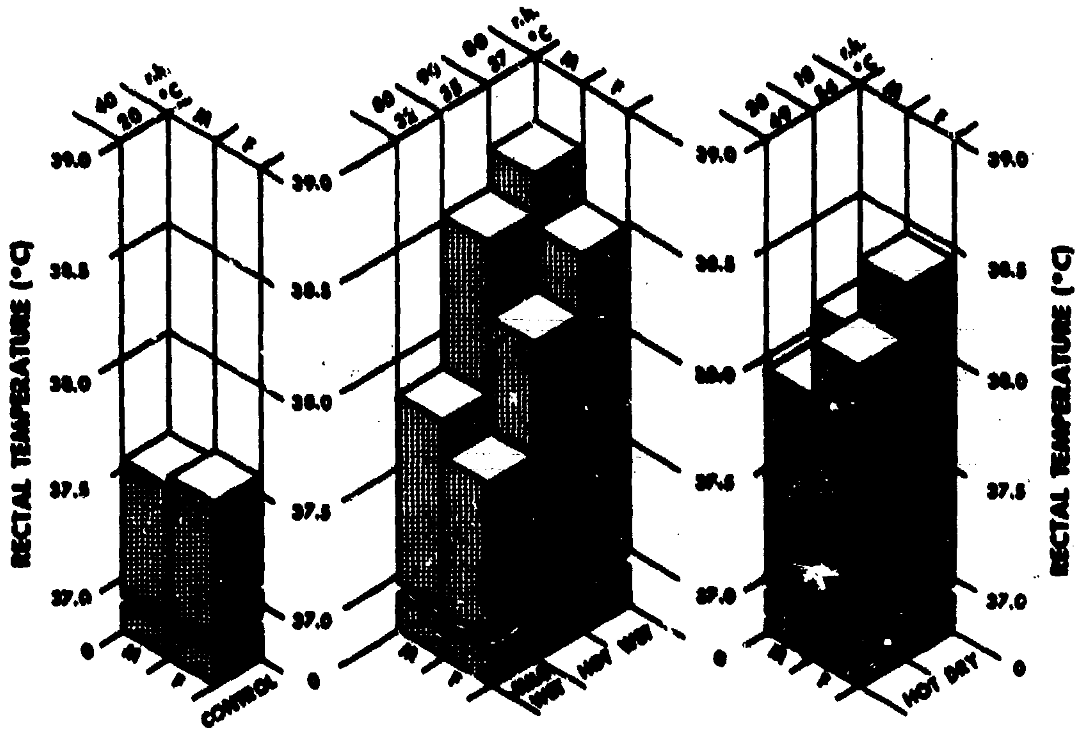

Figure 1. Comparison of mean final rectal temperature (T_{re}) between males (M) and females (F) in a control-comfortable climate (20°C, 40% rh), humid climates (32°C, 80% rh; 35°C, 90% rh; 37°C, 80% rh) and dry climates (49°C, 20% rh; 54°C, 10% rh).

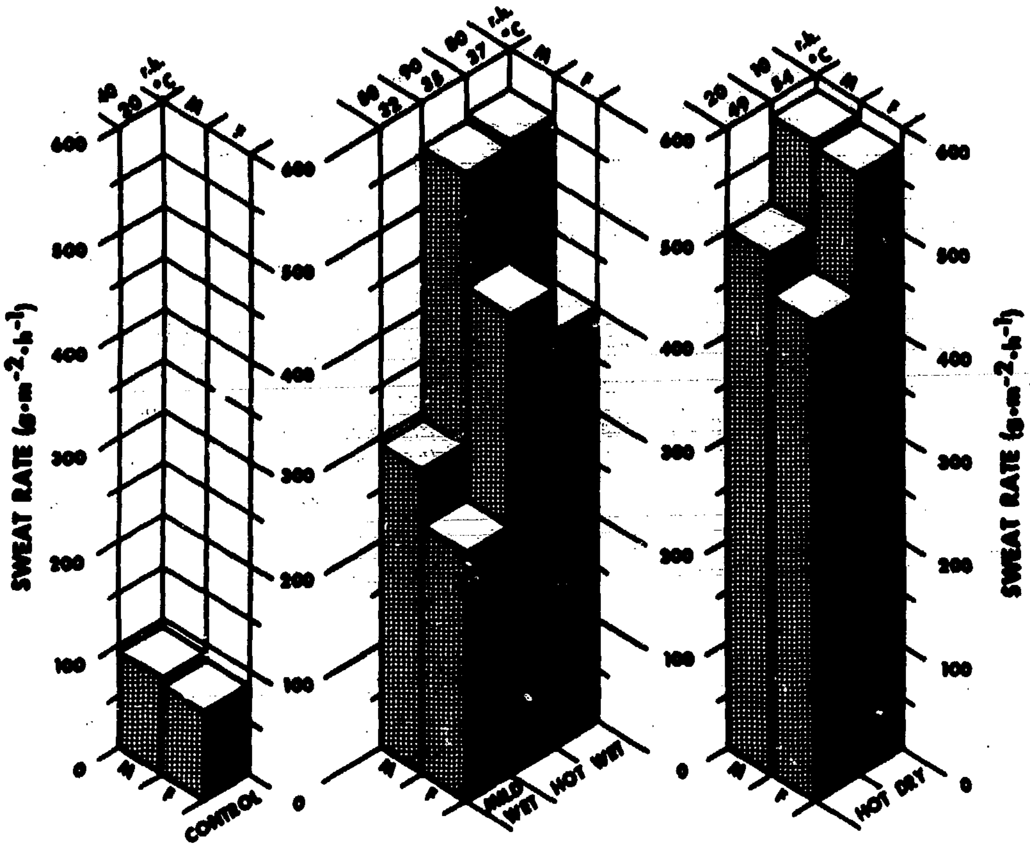

Figure 2. Comparison of mean hourly sweat rate ($\dot{m}_{sw}$-$g \cdot m^{-2} \cdot hr^{-1}$) between males (M) and females (F) in the comfortable climate, the three humid climates and the two dry climates.

TABLE 1 Surface area-to-mass ratio (A_D/wt) and thermoregulation

		FEMALES				MALES			
		Higher A_D/wt		Lower A_D/wt		Higher A_D/wt		Lower A_D/wt	
	No. of Subjects	4		5		5		5	
A_D/wt	($cm^2 \cdot kg^{-1}$)	297 ±	5*	272 ±	6	273 ±	5	244 ±	7
	T_{re}, °C	38.10 ±	0.11	38.27 ±	0.08	37.85 ±	0.11	38.02 ±	0.12
HOT-DRY	T_{sk}, °C	36.30 ±	0.30	36.18 ±	0.50	35.96 ±	0.09	35.64 ±	0.39
	ΔS, $W \cdot kg^{-1}$(1st h)	0.486 ±	0.076	0.635 ±	0.089	0.589 ±	0.055	0.531 ±	0.100
49°C, 20%	HR, $beats \cdot min^{-1}$	131 ±	9.7	130 ±	4.2	116 ±	5.5	118 ±	4.6
	$\dot{M}_{sw}$, $g \cdot kg^{-1} \cdot h^{-1}$	13.83 ±	0.76	12.47 ±	0.57	13.38 ±	0.77	12.59 ±	0.91
	T_{re}, °C	38.35 ±	0.05	38.60 ±	0.09	38.62 ±	0.13	38.84 ±	0.11
HOT-WET	T_{sk}, °C	36.15 ±	0.17	36.44 ±	0.15	36.40 ±	0.10	36.62 ±	0.11
	ΔS, $W \cdot kg^{-1}$(1st h)	0.686 ±	0.022	0.804 ±	0.081	0.834 ±	0.115	1.065 ±	0.046
37°C, 80%	HR, $beats \cdot min^{-1}$	140 ±	4.1	145 ±	4.3	147 ±	7.8	151 ±	1.5
	$\dot{M}_{sw}$, $g \cdot kg^{-1} \cdot h^{-1}$	11.49 ±	1.79	11.19 ±	0.91	14.61 ±	1.04	14.30 ±	0.91

*Mean ± S E

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	The Effect of Physical Training in Air or Water on Heat Tolerance
Investigators:	Barbara A. Avellini, Ph.D., Yair Shapiro, M.D., Kent B. Pandolf, Ph.D., Suzanne M. Fortney, Ph.D., Nancy A. Pimental, Claire M. Kimbrough and Fred R. Winsmann.

Background:

A controversy has arisen in past years regarding the role physical conditioning plays in the attainment and retention of heat acclimation. Physical training would be thought to confer some degree of heat tolerance since physiological changes associated with training are similar to those found during heat acclimation.

The improvement of the functional capacity of the cardiovascular system with training is an important aspect in the enhanced heat tolerance of trained individuals. Training stimulates an increase in blood volume which results in an increased stroke volume at the same cardiac output. It appears that athletes are able to maintain an adequate cardiac output sufficient to meet the combined metabolic and heat dissipating requirements for a longer period of time than can non-athletes (1,2). With a higher stroke volume and lower heart rate, more highly trained individuals will be working at a lower percentage of their heart rate reserve when the strain of high ambient temperatures is added to their physical activity.

While an increase in sweat rate (SR) is postulated to be a primary outcome of heat acclimation, the SR's of trained individuals are not necessarily higher than those of untrained controls (1, 2, 4, 6, 7). However, more fit individuals may have a sweat mechanism which is more sensitive to changes in core temperature than less fit individuals. Thus, for a given sweat rate (and provided free evaporation), the internal temperature of athletes would not rise to as high a level as non-athletes.

It seems reasonable to assume that individuals who achieve their high level of aerobic fitness through swimming would not demonstrate enhanced tolerance to heat since their training in cool water does not produce elevated core temperatures and thus does not stimulate the sweat glands. Indeed, some evidence exists to support the contention. Swimmers did not demonstrate the "preacclimatization" to heat which was evident in long distance runners (5). Swimmers also showed both a longer latent period before thermal sweating was initiated and a significantly lower sweat rate throughout a heat exposure (3).

Progress:

The present study was undertaken to determine if training in water does indeed result in less heat tolerance than training in air. Fourteen male volunteers, who were initially matched with regard to body fat, body surface area and maximal aerobic capacity ($\dot{V}O_2$ max), underwent an intensive four week training program on a bicycle ergometer in air (Group I, n = 4) or in water of either 32° C (Group II, n = 5) or 20° C (Group III, n = 5). The two water temperatures were selected to help differentiate between the mechanisms responsible for the poorer performance of swimmers in the heat. That is, work at 20° C would not elicit an elevated core temperature; while at 32° C, core temperature would rise, but little or no training of the sweat glands would occur since sweating contributes little to the cooling of an immersed individual. The four week training program in all groups consisted of one hour daily (5 times/week) exercise bouts on a bicycle ergometer at 75% $\dot{V}O_2$ max. The exercise level was increased each week to maintain a constant training stimulus. For water training, the subject pedaled a modified Monark bicycle while immersed to his neck in water. The bicycle was modified by removing the friction belt from the flywheel and attaching one to six metal fins which created added resistance to pedaling in the water (Fig 1). The workload was increased by adding fins and/or increasing the pedaling frequency.

The daily exercise elicited an increase in body temperature in Groups I and II, but not in Group III. All three groups demonstrated similar percentage increases in $\dot{V}O_2$ max as a result of the training (~12%).

Before and after training, and again following an 8-day heat acclimation, the subjects were exposed to dry heat (49° C, 20% RH) for three hours each day with each hour of exposure consisting of 10 minutes rest, 50 minutes walk at 5.6 km•hr^{-1}(3.5 mph). Compared to the pre-training heat tolerance test, Groups

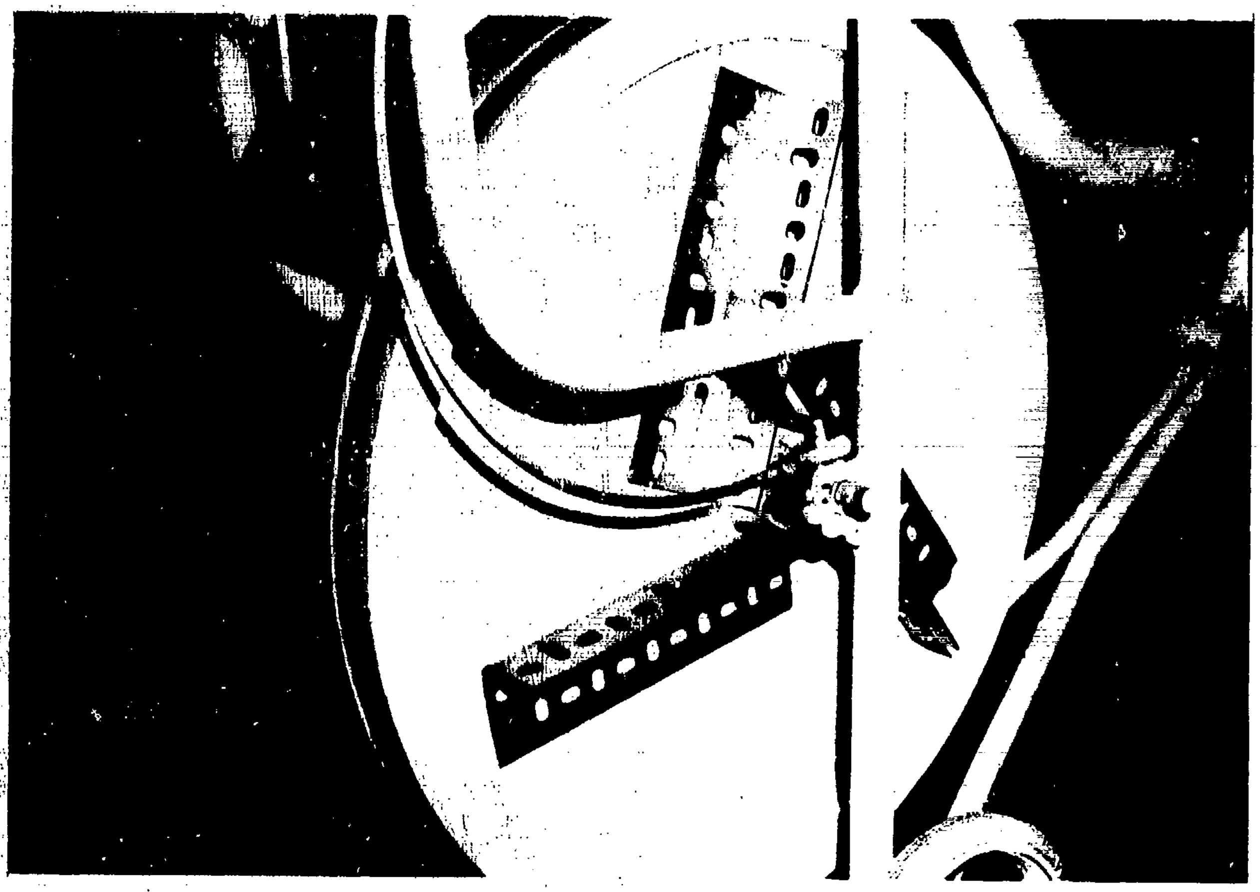

Figure 1. Photograph depicting the modified Monark bicycle with three fins attached to the flywheel.

I and II both showed an increase in tolerance time and a decrease in final rectal temperature (T_{re}) and heart rate (HR) following training (Figure 2). Total body sweat rate increased 12% and 25% in each group, respectively from the pre- to post-training heat stress tests (Figure 3). Following training, Group III demonstrated a decrease in final HR in the 3-h exposure; however, completion time was less and final T_{re} was higher than before training. Total body sweat rate did not increase as a result of training in Group III and was lower than either of the other two trained groups. Following the 8-day acclimatization to the dry heat for 2 hours per day, all groups demonstrated the same completion times, final T_{re}'s and HR's (Figure 2). Sweat rates were also similar in all three groups (Figure 3).

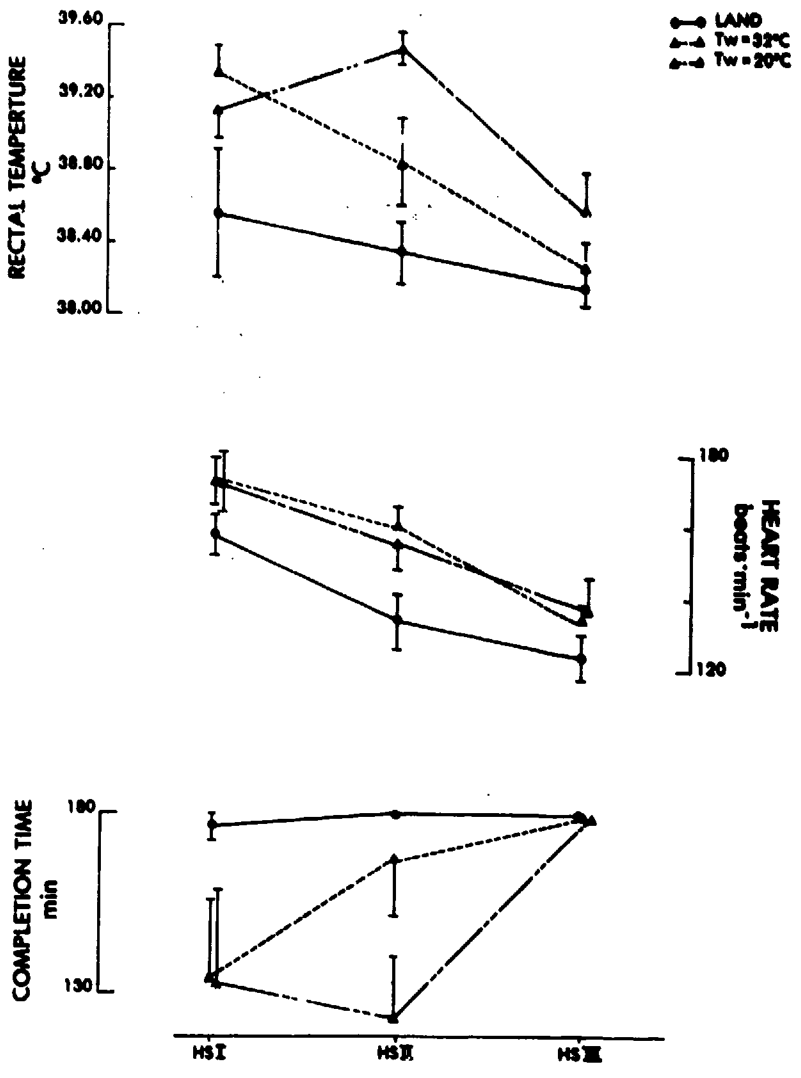

Figure 2. Completion times, final rectal temperature and final heart rate for each of the three groups for the pre-training (HSI), post-training (HSII) and post-acclimation (HSIII) heat stress tests.

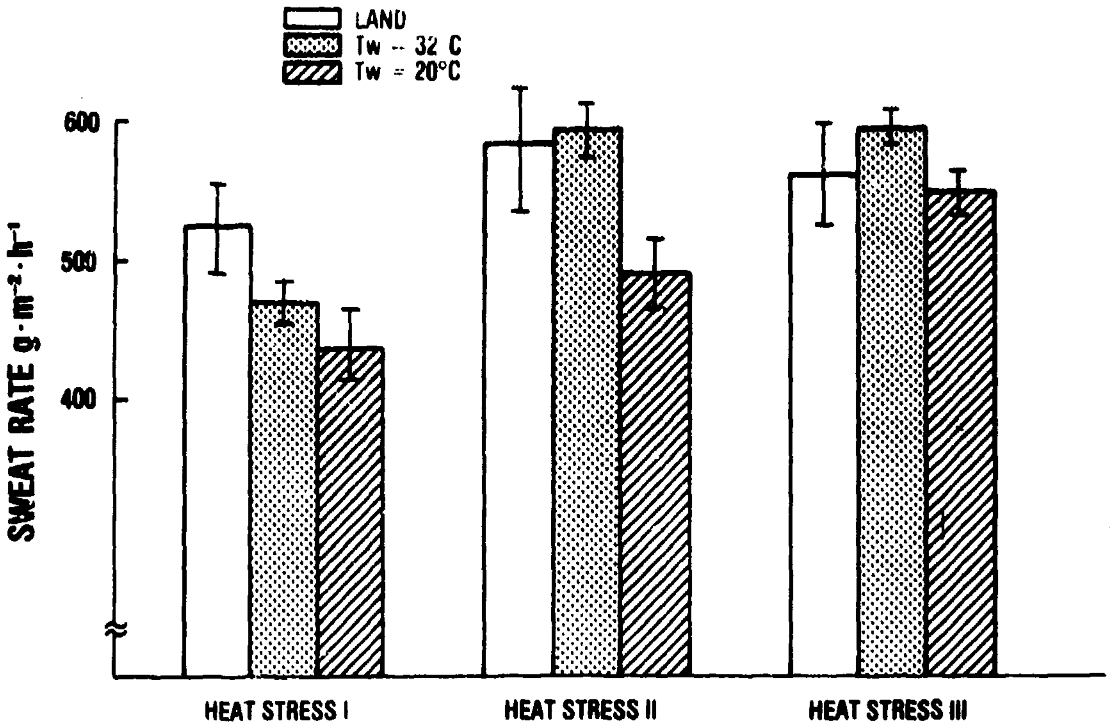

Figure 3. Mean hourly sweat rates for each group for the pretraining (HSI), post-training (HSII), and post-acclimation (HSIII) heat stress tests.

It was concluded that physical training can improve the cardiovascular response to an acute dry heat exposure wihout affecting the thermoregulatory capacity of the body. It appears that training can enhance heat tolerance only if body temperature is permitted to rise during exercise, thus stimulating the temperature-regulating centers for heat dissipation.

Presentation:

Avellini, B. A., Y. Shapiro and K. B. Pandolf. The effect of physical training in air or water on heat tolerance. Presented at the 20th Annual Brouha Work Physiology Symposium, Cambridge, MA, September 1980.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Artificial Heat Acclimatization: Differences Between Cold and Warm Seasons
Investigators:	Yair Shapiro, M.D., Roger W. Hubbard, Ph.D., Claire M. Kimbrough and Kent B. Pandolf, Ph.D.

Background:

Acclimatization is a physiological phenomenon that increases the heat tolerance of man by more effective and efficient heat dissipating mechanisms. Acclimatized men have a lower body temperature, lower heat storage, lower heart rate, and a somewhat higher sweat rate in comparison to non-acclimatized men (1). The end point of acclimatization is conventionally said to occur when the common thermoregulatory parameters (sweat rate, body temperature, heart rate) reach a definitive plateau. Hemodynamically, it has been shown that an expansion of the plasma volume occurs with acclimatization (2).

Artificial acclimatization is a well known procedure to acclimatize men to conditions in a particular experiment or before shifting them to work in hot areas. In nature, man becomes more and more acclimatized during the summer and less so during the winter. The purpose of this study was to compare both the physiological and hemodynamic responses of subjects to artificial acclimation in a hot-dry environment following a cold season (lowest natural acclimatization) and a hot season (highest natural acclimatization).

Progress:

Eight male soldiers (22.5 yr, 175 cm, 69 kg) were acclimated to 40° C, 30% RH by walking 2 hours on a level treadmill for 10 consecutive days on two separate occasions: once at the end of summer (S) and once at the end of winter (W). In addition to measuring heart rate and rectal temperature, blood samples were drawn before and after each daily heat exposure and analyzed for hematocrit, hemoglobin, albumin, and total protein. Sweat rate was determined from weight loss, adjusted for water intake, urine output, and respiratory and metabolic weight losses.

During the 10 days of the S acclimation, both rectal temperature and sweat rate remained unchanged and heart rate decreased. Sweat rate also remained unchanged, during the W acclimation, although both heart rate and rectal temperature decreased (Figure 1).

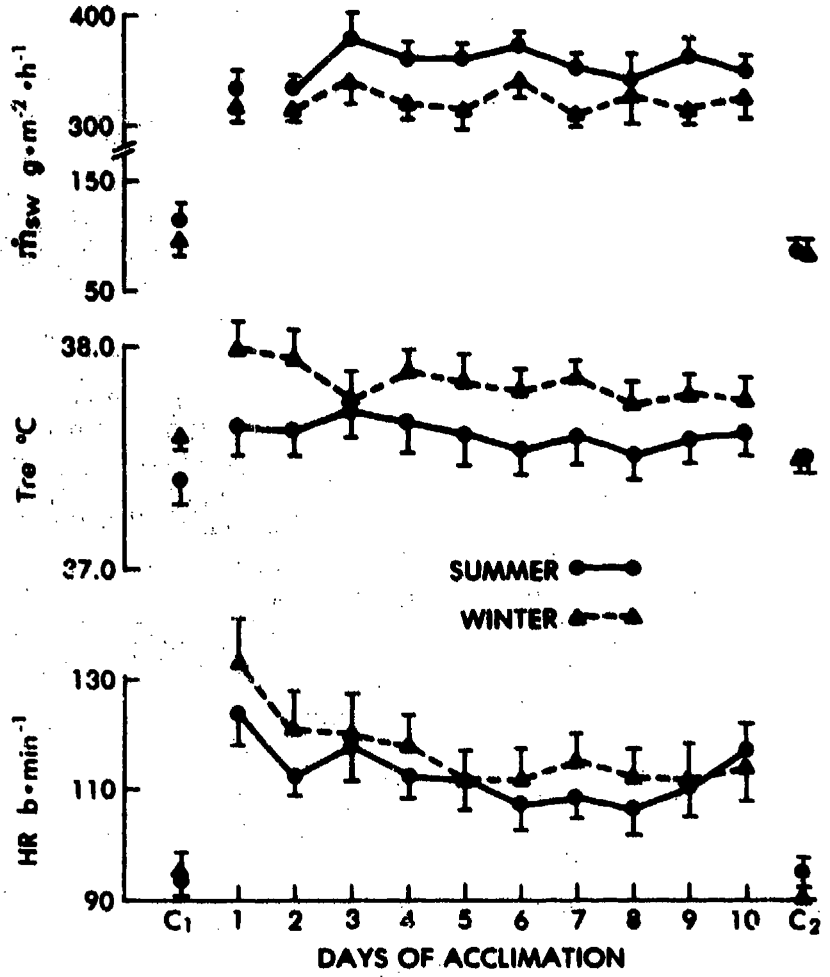

Figure 1. Final sweat rate ($\dot{m}_{sw}$), rectal temperature (T_{re}) and heart rate (HR) values during each day of S and W exposures are displayed. C_1 and C_2 are control days, and 1-10 are the acclimation days.

In comparing the seasons, it was found that rectal temperature during W was consistently and significantly higher (0.15 - 0.35° C) than during S, whereas the sweat rate observed during the S acclimation was significantly higher (5-14%) than during each day of the W exposures. The changes observed in rectal temperature suggest a different thermoregulatory set-point for the different seasons, a difference which cannot be totally eliminated by acclimation. The decrease found in heart rate in both seasons suggests that in terms of cardiovascular adjustment, the subjects were not fully acclimatized either in the winter or in the summer prior to the artifical acclimation.

The hematological results are presented in Table 1. As is evident by the decreases found daily (PRE-POST) in hemoglobin and hematocrit, hemodilution was observed during each day of the actual heat exposure in both S and W.

TABLE 1

Comparison of hematological data for the first control day (C) and first, sixth and tenth days of the acclimation period (A_1, A_6, A_{10}) for S and W, both pre-and post-exposures.

		C_1		A_1		A_6		A_{10}		significance of differences		
		pre	post	pre	post	pre	post	pre	post	S-W	acclimation	pre-post
Hb g%	S	17.0 ± 0.4	17.7 ± 0.4	17.2 ± 0.3	16.7 ± 0.3	15.9 ± 0.2	15.5 ± 0.2	16.4 ± 0.3	16.1 ± 0.3	NS	$A_1 > A_{10} > A_6$	*
	W	17.2 ± 0.6	16.2 ± 0.4	17.0 ± 0.4	16.8 ± 0.3	15.6 ± 0.4	15.2 ± 0.3	15.8 ± 0.4	15.6 ± 0.3			
HCT %	S	46.9 ± 1.0	45.4 ± 0.8	47.8 ± 0.7	45.4 ± 0.8	45.7 ± 0.6	43.7 ± 0.6	47.9 ± 0.8	45.4 ± 0.6	*EA_6	$A_6 < A_1$&A_{10}	*
	W	46.2 ± 1.1	44.0 ± 1.0	45.2 ± 0.9	43.0 ± 0.9	46.3 ± 1.0	44.2 ± 1.3	45.1 ± 1.1	43.3 ± 0.9		NS	
ALB g%	S	4.67 ± 0.08	4.18 ± 0.10	4.56 ± 0.06	4.37 ± 0.07	4.24 ± 0.06	3.88 ± 0.07	4.[illegible] ± 0.09	4.44 ± 0.09	*OA_6	$A_6 < A_1$&A_{10}	*
	W	4.90 ± 0.07	4.66 ± 0.13	4.85 ± 0.07	4.66 ± 0.10	4.87 ± 0.08	4.62 ± 0.10	4.83 ± 0.12	4.60 ± 0.12		NS	
TP g%	S	7.86 ± 0.08	7.69 ± 0.09	7.78 ± 0.07	7.62 ± 0.08	7.36 ± 0.10	7.33 ± 0.06	7.74 ± 0.09	7.47 ± 0.05	NS	$A_6 < A_1$&A_{10}	*
	W	7.76 ± 0.16	7.38 ± 0.09	7.75 ± 0.06	7.49 ± 0.05	7.53 ± 0.13	7.29 ± 0.10	7.61 ± 0.15	7.49 ± 0.10			
ΔPV %	S			base line	6.7 ± 1.6	11.6 ± 2.1	17.9 ± 1.7	4.8 ± 1.8	11.0 ± 2.9	*OA_6	$A_6 > A_1$&A_{10}	*
	W			base line	4.6 ± 2.4	7.0 ± 1.9	13.6 ± 1.9	7.7 ± 1.3	12.2 ± 2.0		NS	
ΔBV %	S			base line	3.0 ± 0.9	8.3 ± 1.2	11.2 ± 1.0	5.1 ± 1.3	7.1 ± 1.1	NS	$A_1 < A_{10} < A_6$	*
	W			base line	1.4 ± 2.1	8.7 ± 1.5	12.1 ± 1.2	7.6 ± 0.7	9.2 ± 1.3			
MCHC%	S	36.3 ± 0.5	39.0 ± 0.5	36.0 ± 0.4	36.9 ± 0.4	34.8 ± 0.4	35.4 ± 0.4	34.2 ± 0.4	35.4 ± 0.3	*	$A_1 > A_6$&A_{10}	*
	W	37.2 ± 0.8	36.9 ± 0.7	37.7 ± 0.6	39.1 ± 0.6	33.8 ± 0.3	34.4 ± 0.5	35.1 ± 0.3	36.0 ± 0.4		$A_1 > A_{10} > A_6$	

In the significance of differences columns: * denotes $P < 0.05$, E = except, O = only, $A_x > A_y$ = values of A_x are significantly ($P < 0.05$) higher than those of A_y, S-W = difference between summer and winter, NS = not significant. Symbols in the middle space apply to both summer and winter.

Throughout the 10 days of acclimation in both S and W an expansion of the blood volume occurred (Figure 2). During the winter this expansion occurred both in the plasma volume and in the cellular volume, whereas only the plasma volume expanded in the summer.

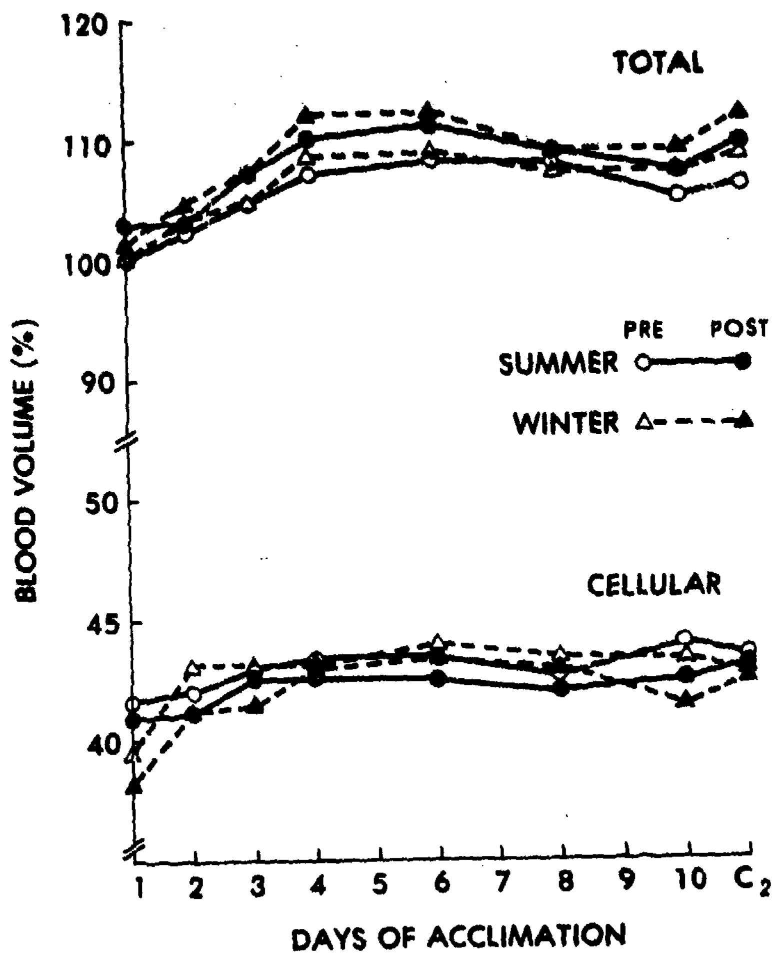

Figure 2. The changes in blood volume and cellular volume during S and W exposures are presented; pre- and post-exposure values for the last control day (C_2) and the ten acclimation days (1-10) are shown. Pre-exposure values of the first acclimation day of each season are defined as 100%.

The authors suggest that these hemodynamic changes were a result of albumin shifting into the vascular space. This suggestion is supported by the unchanged albumin level during the W acclimation, and by the smaller changes in albumin or total protein levels than the changes in plasma volume during the summer.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Comparative Methods of Auxiliary Cooling in Man
Investigators:	Yair Shapiro, M.D., Kent B. Pandolf, Ph.D. and Ralph F. Goldman, Ph.D.

Background:

Less energy is needed to cool a man by cooling his microclimate than by cooling the macroclimate. As an auxiliary cooling method, it has been proven that it is much more effective to use water suits or ice suits than to use a cool air suit. The main problem remaining unsolved is the control of the cooling rate. The most advanced control system was developed by Webb and colleagues (Webb Associates)(1). This system receives inputs from the subject's oxygen consumption and skin temperature and the resultant output is the water temperature of the suit. This control mechanism is very expensive and complicated and not applicable for general use. In Japan and in the gold mines of South Africa they use ice suits (dry ice in Japan and water ice in S.A.). It appears that these suits and especially the water ice variety, are very effective during high work loads in very hot environments. However, the direct contact of the cold surface with the skin is unpleasant and may induce local cold injury (especially with dry ice suits).

We suggest that if the ice in the suit is replaced by materials which melt at a temperature closer to the skin temperature, the skin itself will be the regulator and control mechanism of the cooling rate.

Exposure to cold produces peripheral vasoconstriction and a decreased skin temperature. Thus, the temperature gradient from skin to suit decreases and becomes closer to zero. When the body accumulates heat the peripheral blood vessels vasodilate and the skin becomes warmer. Thus, the temperature gradient skin to suit becomes greater and the heat transferred between the body and the suit will be greater. Potentially, there are two problems with this concept:

(a) the material substituted for ice has to be nontoxic and (b) it has to have a high latent heat of fusion, as close as possible to that of water. We know of two nontoxic materials (a) $C_a\ Cl_2 \cdot 6H_2O$ and (b) acetic acid; the first one melts at 24.4°C and the second at 16.6°C, but the latent heat of both of them is 50-55% of water. Thus, the total "cold content" of such suits will be about half of that of water, or for the same effect the suit would have to be twice as heavy. The problem can be solved by developing a two layer cooling suit; the inner layer - high melting point - thin and close to the skin, and the other - one of ice -thicker than the inner one. The aim of this study is to develop an effective and safe auxiliary cooling suit for man.

Progress:

This study is in the stage of collecting the different suits from various places. We are experiencing a great deal of difficulty in securing the appropriate cooling suits to be evaluated under this protocol.

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Program Elements: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Prediction of Sweat Rate and Heat Tolerance

Investigators: Yair Shapiro, M.D., Leander A. Stroschein and Kent B. Pandolf, Ph.D.

Background:

Three major physiological factors determine the ability of soldiers to operate in hot climates: body temperature, cardiovascular adjustment and water balance. Models to predict body temperature and heart rate have been developed at this Institute; they have been validated for many combinations of environmental conditions, physical activity, clothing and external load carried by the soldier. These mathematical models predict the heart rate and rectal temperature at any given time, and tolerance limits; however, they did not predict water balance and its effects on tolerance. The metabolic heat production, clothing heat transfer characteristics, and the environment do predict the evaporative cooling required by the body (E_{req}) to maintain thermal balance. However, the maximal evaporation to the environment (E_{max}) is dictated by the vapor transfer properties of the clothing and the vapor pressure between the skin and the air. The absolute values of E_{req} and E_{max}, and the relation between them, dictate the thermoregulatory balance of the body and the associated water requirement (sweat) for this thermoregulation.

The purpose of this study was to develop a comprehensive mathematical model to predict sweat rate for a wide range of environmental conditions, energy expenditures and clothing ensembles.

Progress:

Thirty-four acclimatized male soldiers (volunteers) participated in this study. They were divided into three groups and exposed two hours to five climate combinations (air temperature 20-54°C, relative humidity (10-90%); with three metabolic levels (rest, 1.34 $m \cdot s^{-1}$ level walking, 1.34 $m \cdot s^{-1}$ 5% grade walking); and three clothing ensembles (shorts and T-shirts, tropical fatigues, C.B.R. suits). Each two-hour test involved: 10' rest, 50' work, 10' rest, 50' work. Physiological measurements included heart rate, rectal temperature, mean skin temperature, energy expenditure and sweat loss. E_{max} and E_{req} were calculated from environmental conditions, metabolism, clothing insulation and permeability as follows: (1,2)

1. $E_{req} = M_{net} + E_{R+C}$ Watts/m^2

where: $M_{net} = M - 0.098\ W_t \cdot V \cdot G / A_D$

M - metabolism (W/m^2), W_t - body weight(kg), V - walking speed ($m \cdot s^{-1}$)

G - walking grade (%), A_D - body surface area (m^2)

and $E_{R+C} = \frac{6.47}{clo^*}(T_a - T_s)$ W/m^2

clo* - effective clothing insulation coefficient,

T_a - ambient temperature (°C), T_s - mean weighted skin temperature (°C)

2. $E_{max} = 14.2\ (i_m/clo)^* \cdot (P_s - P_a)$ W/m^2

where: $(\frac{i_m}{clo})^*$ - effective permeability index

P_s - water pressure of the skin (mmHg)

P_a - water pressure of the air

The ratio of E_{req} to sweat rate was found to correlate well with E_{max} (Figure 1). Also, the correlation between predicted and measured sweat loss is high (Figure 2). The predictive equations for sweat rate were:

Sweat rate = $27.9\ E_{req} \cdot (E_{max})^{-0.455}$ $g \cdot m^{-2} \cdot h^{-1}$

Since sweat rate equals water required, these equations can be used to predict the body's need for water replacement, and eventually the logistical requirements for water in support of combat operations.

The present formula was derived from 250 exposures to a wide range of environmental conditions (cool, warm, hot, dry and humid) with a variety of clothing ensembles (light clothing, heavy clothing, high permeability and low permeability) and different metabolic rates (rest, 300 and 450 W). Therefore, our prediction equation can be used for a wide range of E_{req} (50 - 360 $W \cdot m^{-2}$) and of E_{max}($20 - 525\ W{\cdot}m^{-2}$). The verification of the present model using results published by other investigators (see Figure 3) supports this suggestion. The main limitation for the present prediction model appears to be at at very high sweat rates. In this case, the formula appears to overestimate the sweat rate; in one exposure in our study, when the measured sweat rate was 932 $g{\cdot}m^{-2}h^{-1}$, the predicted value was 1190 (overestimation of 28%). In this condition, it can be assumed that the actual sweat rate was close to the maximal sweat rate, so the sweating mechanisms were saturated and subjects could not "reach" the values predicted as required to achieve a steady state thermoequilibrium.

In general, however, we suggest that sweat rate can he predicted simply as a function of E_{req} and E_{max} for a wide range of climatic conditions, clothing ensembles and metabolic rates. The present sweat rate prediction model is more comprehensive than other existing models because it allows for prediction over a wider range of total heat load (metabolic heat production and heat exchange with the environment), and evaporative cooling capacity with greater applicability to different clothing systems. The present model predicts the sweat rate more accurately than the other existing models especially in extreme climatic conditions. The prediction of sweat rate using the formula in the present study instead of the nomograms used in two of the other models can be an added advantage of this model because of the wide usage of calculations and advanced state of computer technology.

<u>Presentation:</u>

Shapiro, Y., K. B. Pandolf, J. R. Breckenridge, and R. F. Goldman. Predicting sweat rate from E_{req} and E_{max}. Fed. Proc. 38, Part II:1052, 1979.

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2. Givoni, B. and R. F. Goldman. Predicting heart rate response to work, environment and clothing. J. Appl. Physiol. 34:201-204, 1973.

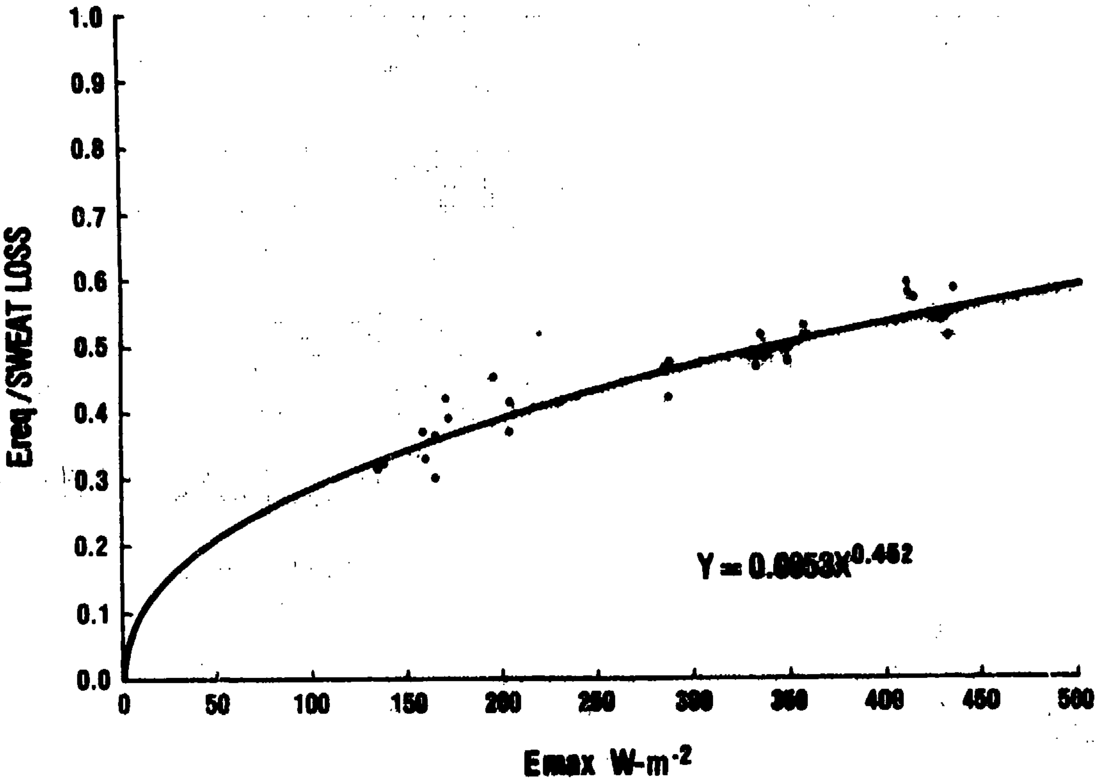

Figure 1. Correlation between E_{max} and E_{req}/sweat loss ratio (males).

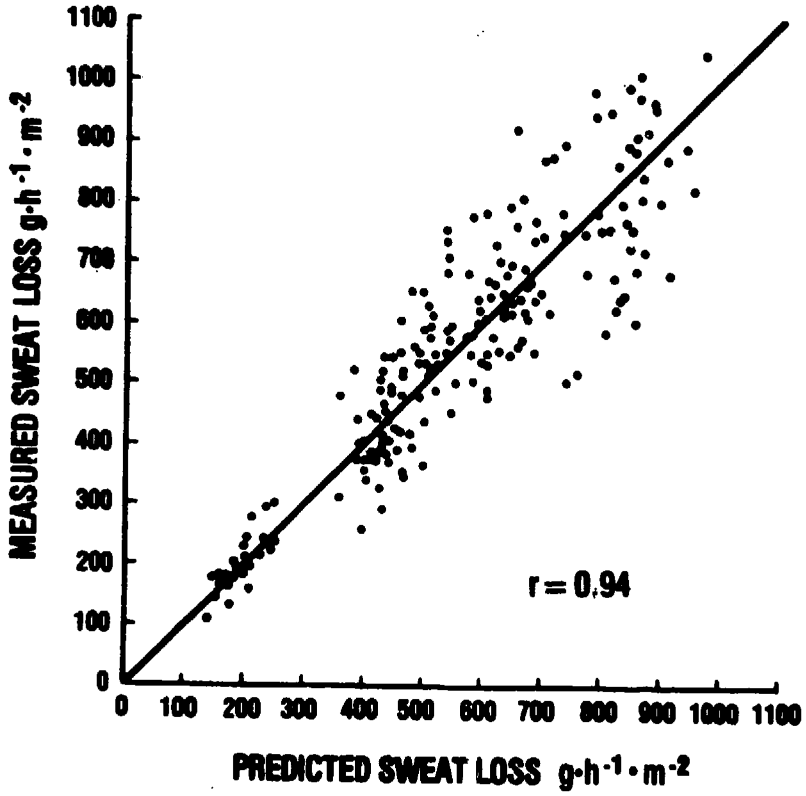

Figure 2. Correlation between predicted sweat loss and measured sweat loss (males).

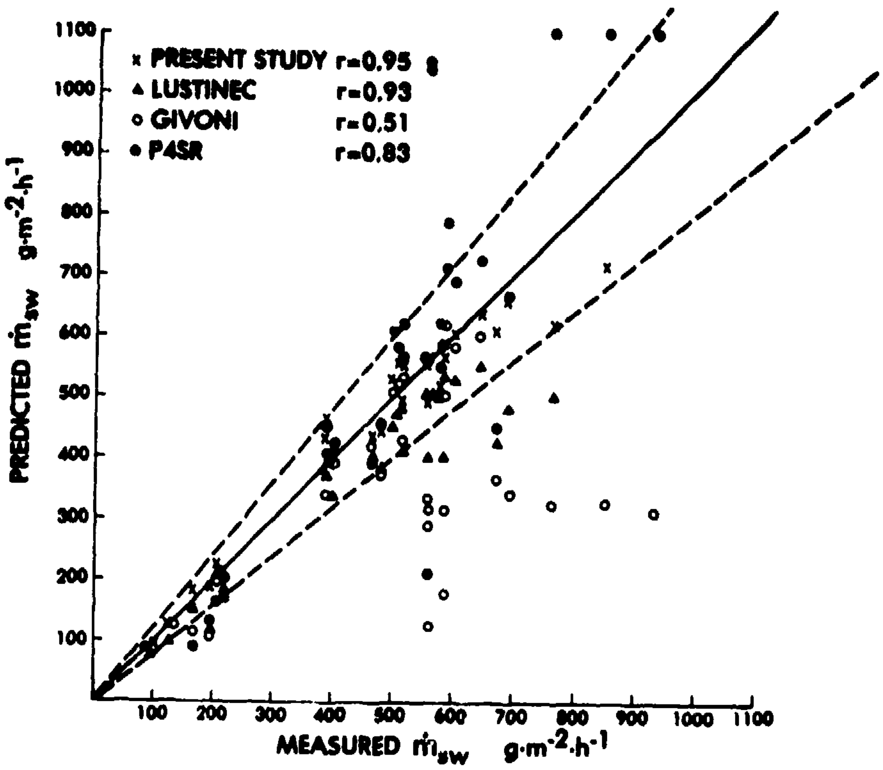

Figure 3. Comparison of four methods to predict the sweat rate observed in present study. The solid line is the line of identity and the dashed lines present the + 20% range from this line of identity.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Collaboration and Prediction Modeling in Clinical Evaluations of Hyperthermia (T_{re}~42°C) at the National Cancer Institute
Investigators:	Kent B. Pandolf, Ph.D., Gaither D. Bynum, M.D., Joan Bull, M.D., Leander A. Stroschein and Ralph F. Goldman, Ph.D.

Background:

The concept of critical thermal maximum (CTM) has been defined in the literature as the minimum nigh deep body temperature which is lethal to an animal (2). In man the CTM has been estimated at 41.6°C - 42.0°C (4). However, we previously reported data for sedated unacclimatized, well-hydrated men (cancer patients) heated one hour until esophageal temperatures of 41.6°C - 42°C without sequelae, except for modest elevations of serum enzymes in 2 of 5 patients (1). These data, when combined with other observations in the literature (3), suggest that CTM be redefined as the particular combination of exposure time at elevated body temperatures which results in either subclinical (CTM_s) or clinical (CTM_c) injuries.

The second major concept in our report involved the presentation of a mathematical technique equivalent time at 42°C ($T_{eq}42^{o}$), for expressing hyperthermia in terms of body temperature and exposure time. The regression equation for these mathematical functions is of the form, $T = ae^{-bt}$ where "a" and "b" are constants, and T is the temperature in °C. Time - temperature exposure data may then be normalized into equivalent times at 42°C, by use of a modified regression equation. This equation is determined by solving the original equation for "a" using the approximate average rate constant "b" ($b = 1.353$) from our data, along with a time increment equal to 1 and a temperature T of 42°C.

The value for "a" obtained in this manner is equal to 4.7178×10^{24}. Temperature records may then be normalized to equivalent times at 42°C by the summation of the following expression:

$$42°C \text{ equivalent time } (\Delta \text{ Time}/4.7178 \times 10^{24})e^{-1.353T}$$

Progress:

Currently, over 40 cancer patients have been evaluated during hyperthermic exposures at the National Cancer Institute (NCI). Multiple hyperthermic exposures (6 or more exposures) have been conducted on little more than half of this group of patients. The goal of our Division is to retrieve the cardiovascular and thermal response data of these patients, and to analyze and organize these findings. However, a sufficiently large cohort must be evaluated in terms of multiple hyperthermic exposures in order to effectively model these responses. Hopefully, the cohort evaluated at NCI will grow sufficiently during FY81 to make data acquisition worthwhile. The last phase in the completion of this study will involve the prediction modeling of hyperthermia which is contingent upon the results from these volunteer patients. Both the acute physiological changes associated with induced hyperthermia and the acclimatization responses with repeated exposures are valuable for modeling purposes. Unfortunately, the mortality rate associated with these volunteer cancer patients has resulted in a lengthy time period in order to achieve the latter objective (acclimatization responses). Nevertheless, these observations will serve as a data base for physiological responses associated with passive hyperthermia and will be most constructive in assessing factors which contribute to heat exhaustion collapse. While no new data collection will be initiated at USARIEM, collaborative contact at NCI on this project will be continued. Also, travel budget constraints have somewhat hampered our ability to support a research team to retrieve these data.

Presentations:

1. Bynum, G., K.B. Pandolf and R.F. Goldman. Human hyperthermia induction: Comparison of circulating water suit with other methods. Fed. Proc. 36:512, 1977.

2. Bynum, G., K.B. Pandolf, R.F. Goldman and J. Bull. A comparison of current methodologies for induction of human hyperthermia. Proc. of the Intern. Union of Physiol. Sci. 13: 112, 1977.

Publications:

1. Bynum, G. D., K. B, Pandolf, W. H. Schuette, R. F. Goldman, D. E. Lees, J. Whang-Peng, E. R. Atkinson and J. M. Bull. Induced hyperthermia in sedated humans and the concept of critical thermal maximum. Am. J. Physiol. 235:R228-R236, 1978.

2. Bynum, G. D. and K. B. Pandolf. The concept of critical thermal maximum (Editorial). Am. J. Physiol. 237:R367-R368, 1979.

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1. Bynum, G. D., K. B. Pandolf, W. H. Schuette, R. F. Goldman, D. E. Lees, J. Whang-Peng, E. R. Atkinson and J. M. Bull. Induced hyperthermia in sedated humans and the concept of critical thermal maximum. Am. J. Physiol. 235:R228-R236, 1978.

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4. Shibolet, S., M. C. Lancaster and Y. Dannon. Heatstroke: A Review. Aviat. Space Environ. Med. 47:280-301, 1976.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Assessment of Thermal Stress in the XM-1 Tank and its Alleviation by Liquid Auxiliary Cooling
Investigators:	Ralph F. Goldman, Ph.D., Barbara A. Avellini, Ph.D., Clement A. Levell, Leander A. Stroschein, Michael M. Toner, CPT, MSC and Robert E. White, CPT, ARMOR

Background:

The potential problem of severe heat stress in crewmen of the new XM-1 Tank has been the concern of DOD when full chemical protective clothing systems (i.e. mission-oriented protective postures (MOPP) are employed in a hot, desert environment. The evaluation of the heat stress and its potential alleviation by an auxiliary personal cooling system has been undertaken at the Yuma Proving Grounds (YPG), Arizona. The experimental approach which has previously been used in the Military Ergonomics Division (1) includes a preliminary computer model prediction of deep body temperature (T_{re}) and heart rate (HR) responses of men (2, 3) wearing the combat vehicle clothing (CVC) plus MOPP IV. This approach includes the worst case thermal environmental conditions measured in the XM-1 Tank, parked in full sun with the engine running. In this way, the probable safe exposure times are predicted. The effects of the auxiliary cooling system are also predicted based on copper manikin measures of cooling power taken in the laboratory before departing for YPG. Human testing is performed within a predicted thermal stress "window" (i.e., set of environmental and clothing conditions) which will produce significant heat stress (low end of the window) but not result in an unacceptable rapid rise of T_{re} with its accompanying risk of heat stroke (high end of the window). Based on the low heat production of the combat vehicle crewman, the XM-1 window for human test exposure is projected to be the 85-95°F WBGT range without auxiliary cooling.

Progress:

Two tank crews (4 per crew) alternating days of heat exposure were individually monitored by 3 point skin temperature ($\bar{T}_{sk}$), T_{re}, HR and pre- to post-, nude and clothed, body weights. Testing conditions included six days of heat exposure in the XM-1 Tank with various CW and tank postures. They included: Day 1, CVC only with tank hatches (HT) open and ventilators (VT) on; Day 2, CVC plus MOPP III with HT open and VT on; Day 3, CVC plus MOPP IV with HT open and VT on; Day 4, CVC plus MOPP IV with HT closed and VT off; Day 5, CVC plus MOPP IV, auxiliary cooling vest, HT closed, VT off; Day 6, CVC plus MOPP IV, HT closed, VT off. Each exposure included a combination of rest and work periods. The work periods consisted of 3 simulated fire missions per hour of exposure. The least exerted crewman during each fire mission was the Driver (D) who manually closed and opened his hatch. The Loader (L) removed and re-loaded one dummy round (~36 lbs) three times. Each round was moved from the ammunition rack to the chamber without need of vertical lifting of the round. The Tank Commander (TC) was required to stand on his chair and rotate his weapon station. The Gunner (G) remained seated and manually rotated the turret. Each fire mission represented approximately 4 minutes of activity. Therefore, 12 minutes out of the hour, the crew was engaged in light to moderate activity.

Environmental conditions were similar inside as opposed to outside the XM-1 Tank when the HT were open and the VT on. WBGT inside the tank averaged 86.9, 80.2 and 82.6^{o} F on Days 1-3 respectively. Closed HT conditions with VT off increased heat stress; WBGT averaged 95.0, 90.5 and 92.1^{o} F on Days 4-6 respectively and was considerably higher than Days 1-3 due to the increased relative humidity in the tank which, for instance, averaged 91% on Day 6.

The heat stress on the individual crewman was slight to moderate on Days 1 and 2 and did not appreciably affect physical performance in the tank. T_{re} on all but one crewman remained below 100^{o} F and gradient between T_{re} and $\bar{T}_{sk}$ was between 3.8 to 5.0^{o} F. Heart rates averaged 86 b$\cdot$min^{-1} on Day 1 and 75 b$\cdot$min^{-1} on Day 2.

Day 3 represented a similar environmental condition inside the tank as compared with Day 2. However, the addition of full CW ensemble created a much greater heat stress. T_{re} averaged just under 100^{o} F and T_{re} to $\bar{T}_{sk}$ gradients ranged between 1.6 to 2.6^{o} F. Heart rates averaged 105 b$\cdot$min^{-1} and ranged from 76 b•min^{-1} for the D to 133 b•min^{-1} for the L. Subjective evaluation of performance ability at the end of the three hour exposure was considerably reduced and ranged from 50-90% of normal.

Days 4 and 6 presented the crewman the greatest heat stress conditions. Exposures were terminated early due to physiological as well as psychological distress to the crewman. Day 4 was terminated at minute 80, with crew T_{re} ranging from 100.8° F for the D to 102.2° F for the TC. T_{re} to $\bar{T}_{sk}$ gradients at termination were depressed because of the high vapor pressures in the tank and ranged from 0.6° F to 1.2° F. Final HR averaged 149 b•min^{-1} with the G peaking at 178 b•min^{-1}. Day 6 was similar to Day 4 although WBGT was 3° F lower. Exposure was terminated in just over 2 hours with convergence of $\bar{T}_{sk}$ and T_{re} in the G. Final T_{re} averaged 101.2° F while final HR averaged 136 b•min^{-1} at the end of exposure.

With inside environmental conditions similar on Day 5 as compared to Day 6, the auxiliary cooling system substantially attenuated the heat stress on the individual crewman. The cooling vest, which circulated 64°F water over the back and chest, increased the range of final T_{re} - $\bar{T}_{sk}$ gradients to 3.5 - 15.4° F. After 208 minutes in the tank, T_{re} averaged just over 100° F and HR averaged 100 b•min^{-1}.

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3. Givoni, B. and R.F. Goldman. Predicting heart rate response to work, environment and clothing. J. Appl. Physiol. 34:201-204. 1973.

(128)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OC 6121	80 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 10 01	R.CORRECTION	U	U		NL	☒YES ☐NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	62777A	3E162777A879	BE	128
b. FORMER	6.27.77.A	3E162777A845	00	055
c. XXXXXX	STOG 80-7.2:4			

11. TITLE (Precede with Security Classification Code) (U)Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 013400 Psychology; 016200 Stress Physiology; 005900 Environmental Biology; 007900 Occupational Medicine; 002300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 80	9.0	229
	CURRENT 81	8.0	160

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME: BANDERET, Louis E., Ph.D.

TELEPHONE: 955-2802

SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: STOKES, James W., LTC, MC

NAME: FINE, Bernard J., Ph.D. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Team Performance; (U)Environmental Stress; (U)Sustained or Continuous Operations; (U)Fatigue, Mental; (U)Psychomotor & Cognitive Functions; (U)Motivation

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Level of training, task organization and small unit "cohesion" are significant determinants of performance and of biological reaction in scenarios where units must fight for sustained periods or in adverse climates or microenvironments. This work unit quantifies, correlates and describes in actual military contexts the interaction of: 1) harsh environmental conditions; 2) common military stressors such as mission demands, noise, crowded work space, and sustained operations with disrupted sleep; 3) the acute physiological, biochemical, symptomatic and psychosocial status of team members; 4) individual and team operational effectiveness over time.

24. (U) Fire Direction Center FDC teams from Artillery units were tested for extended periods in naturalistic combat simulations of that "model" command/control and communications system. Multidisciplinary data are analyzed to assess operational as well as biological cost to teams functioning under complex stress, determine rates of recovery following exposure, identify predictors of operational degradation, and establish mechanisms of action. Collaboration in training exercises and Operational and FDTE field tests of other DA agencies is extending the methodology to other Army teams and perfecting experimental "models" to test prophylactic or therapeutic interventions.

25. (U) 79 10 - 80 09 Reports (Army Science Conference and a NATO subgroup) presented findings from 82nd ABN Div FDC teams (1977 studies), relating internal team communication with performance or omission of self-initiated tasks. Analyses of team member performances and roles continue. Consultation and planning continues with UASFAS for a field test to quantify the impact of physical and mental fatigue in 155mm howitzer crews during high workload, sustained operations. A training simulation for battalion command groups at Ft. Leavenworth was evaluated for collaborative research use. A study of individual factors leading to attrition of students in the MOS 05H course at USAISD, (Ft. Devens) was initiated.

*Available to contractors upon originator's approval

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	055 Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations
Study Title:	Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Sustained Combat
Investigators:	L. E. Banderet, Ph.D. and J. W. Stokes, LTC(P), MC

Background:

When military biomedical research addresses practical problems, the military scientist must evaluate if biological and behavioral phenomena have real-world consequences for military planners and users. In addition, findings must be translated into a suitable framework so planners can anticiate how such consequences will degrade (or sustain) the operational capability and effectiveness of military personnel. In evaluating conditions which affect human performance including the physiological and psychological responses to stress, the scientific literature (1-5) indicates the importance of task, personnel, and organizational variables. These include: task complexity, task structuring, feedback, level of training, intrinsic task interest, experience, motivation, social, and organizational factors. Concerns are often expressed as to the generality and predictive validity of past studies which have not incorporated such variables inherent in many real-world tasks.

To address these issues and provide a framework for communicating research results to the military community, the Field Artillery Fire Direction Center (FDC) was selected as a model. FDCs are common and critical to most ground combat operations. They perform complex command/control, communication and computational tasks requiring both speed and accuracy in which mistakes can cause death even in peace-time exercises. FDC timeliness and accuracy can be measured readily, and elaborate scenarios of events can be presented to them by roleplayers in naturalistic, interactive laboratory simulations which assess not only technical skill but also higher levels of coordination and judgment.

In 1977, four 82d Airborne Division FDC teams, each consisting of five male volunteers, were tested under intense operational demands and sleep-depriving conditions in a laboratory simulation of their military functions (6-8). Teams 1 & 4 were each advised they would undergo an 86 hours sustained operations challenge. Teams 2 & 3 were informed they would each experience two 36-42 hours challenges separated by a 30-36 hours rest period. Operational demands were standardized so that similar events of differing complexity and urgency and two prespecified "lulls" recurred every 6 hours throughout the sustained operations. Lulls were simply 12 minute intervals when no new operational demands were directed to the FDC; however, message traffic irrelevant to the FDC continued on the simulated radio nets. Detailed descriptions of these operational demands, associated individual and team duties, and consequences for performance, as well as data on performance degradation have been presented elsewhere (7).

Pr gress:

The FDC team studies (6-8) provided opportunities to quantify changes in interpersonal communications in small Army teams during acute exposure to environmental stress and fatigue and to determine if such changes were related to operational performance. Although work loads and study periods were roughly equivalent for the teams studied, differences in performance and general outcomes provided opportunities for evaluating the interplay of various communication, individual, and organizational factors.

One type of task demand, preplanning, required processing target messages and sending the firing data for each target to the guns as soon as possible. Examining latencies and percentages of demand completed for various preplanned target processing activities (i.e. preplanning, prioritizing, revising, and updating) had the advantage of assessing risk of serious mission failure for the total population of preplanned targets (7). It was found that these "secondary tasks" (which involved minimal external cueing, had to be time-shared with other activities, and received little feedback for performance, even though highly important) were more vulnerable to sleep-deprivation than were the externally initiated and reinf ced tasks (fire missions).

Preplanning latencies and percent of task completed by the 4 teams were described previously (8), but are summarized in Figure 1 for correlation with new findings. Teams 1 & 4 showed increased latencies after 18-24 hours and, after 36 hours, failed to process several prelanned targets. In the second challenges of Teams 2 & 3, processing times increased after 24 hours. Team 2 was very proficient; their latencies were approximately 25% those of other teams.

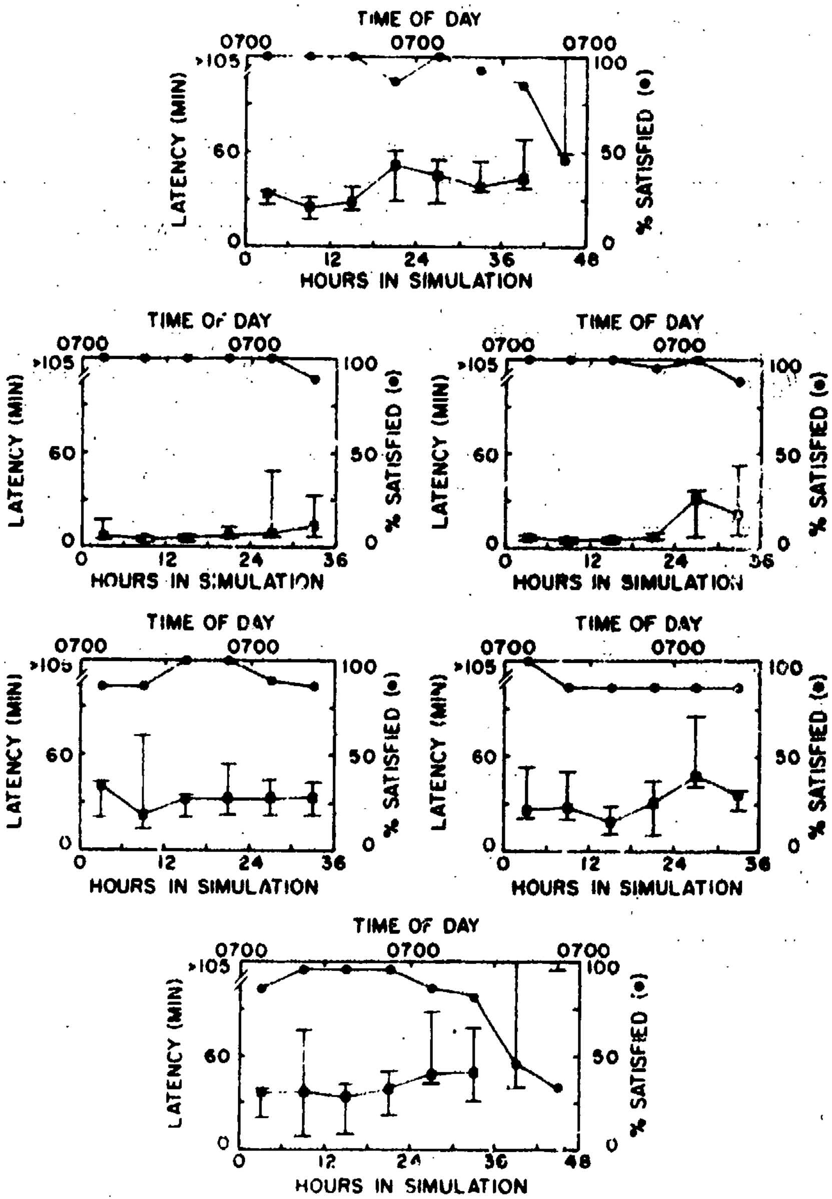

Figure 1. Preplanning latencies for Teams 1,2,3, & 4 (top to bottom) are shown as a function of hours in the simulation. The squares with lower and upper points indicate the 50th, 25th, and 75th percentiles, respectively. Values plotted above the break on each left ordinate were > 105 min. Also shown are the percent of preplanning demands satisfied for each 6 hours (solid circles).

Figure 2, also presented in previous reports (8), shows the latencies and percent of task demand completed for the prioritizing aspect of preplanned target processing. This task involved specifying to the guns which preplanned target was of greatest importance to the forward observer and calling ballistic data to the guns, if not communicated previously. Teams 1 and 4 showed increased latencies for prioritizing after 18 hours. Teams 2 and 3 were more proficient and consistent in their prioritizing but, as with preplanning, Team 2's prioritizing was impaired after 18 hours in the second challenge.

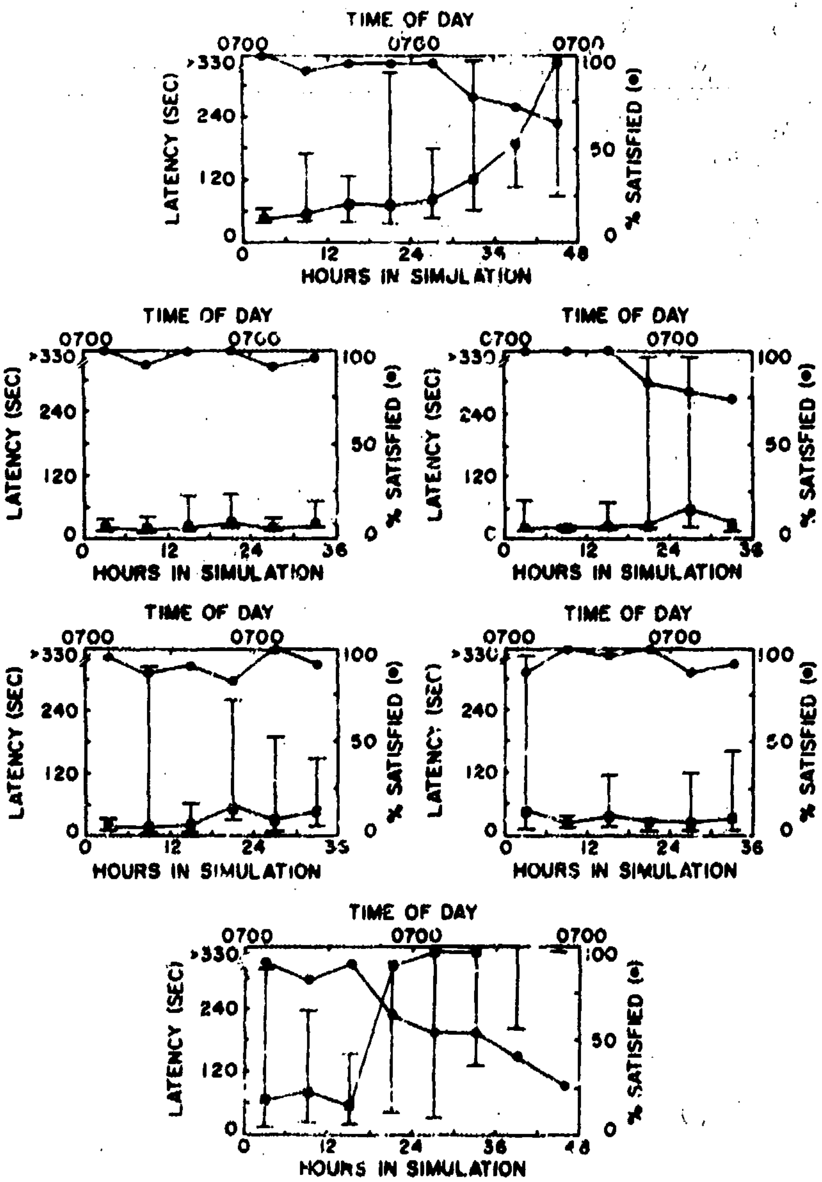

Figure 2. Prioritizing latencies for Teams 1,2,3, & 4 (top to bottom) are shown as a function of hours in the simulation. The squares, with lower and upper points, indicate the 50, 25, and 75th percentiles, respectively. Values plotted above the break on each left ordinate were > 330 seconds. Also shown are percent of prioritizing demands satisfied each 6 hours.

It is notable that the number of prioritizing demands never satisified increased after 18-30 hours in Teams 1, 2 (second challenge), and 4. This is shown in Figure 3. Our initial hypothesis was that this occurred simply as a natural consequence of the teams' increasing latencies for the initial preplanning tasks; i.e. the teams were unable to specify the new priority target's data to the guns, because they had not yet been computed. However, as Figure 3 shows, this was only rarely the case. In fact, for Teams 1,2,3, and 4, ballistic data were already at the guns on 87, 94, 96, and 67% of the occasions when each team's sergeant failed to specify a target as priority. Although in these circumstances each sergeant needed only to announce the priority target number to the guns, all but one increasingly failed to do so after some time in the sustained simulation.

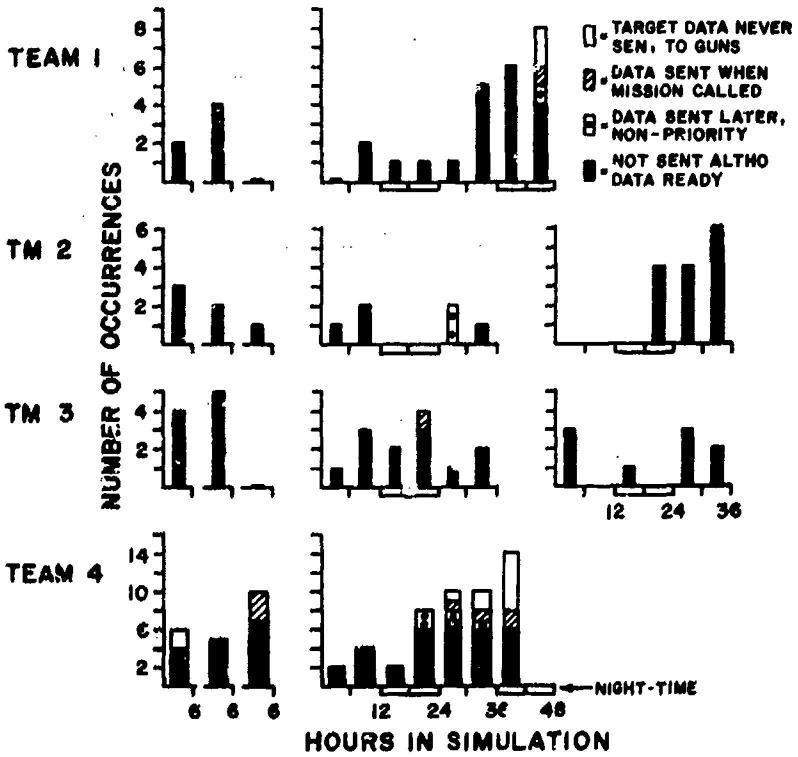

Figure 3. The occasions when the FDC failed to transmit a change in priority target to the guns are shown for all four teams as a function of duration of operations. The solid bars indicate that the change was not announced even though the guns had previously received ballistic data for the target involved. Other symbols indicate that data were sent later without prompting but were not identified as having priority; were sent in response to a fire mission; or were never sent for that target.

It is apparent that these failures did not represent gross inabilities to perform, but were subtle lapses of internal FDC communications. From the video records, we do not believe that these lapses involved micro-sleep, the well-known phenomenon which occurs in sleep-deprived subjects. Instead, we suspect that with sleep-deprivation, personnel in the FDC became increasingly involved in performing their tasks, attending so much to detail that at times they did not integrate their activities with other team members or insure that others acted on their transmissions. So, in this critical military task, the radio-telephone operator often heard the message and faithfully recorded it in his log, but did not insure that the sergeant (who was preoccupied with computing data) heard and transmitted the message to the guns. Additional analyses are being conducted to document how this critical performance was not maintained or compensated for by other team members.

The military importance of this observation lies both in the potentially critical consequences of such FDC failures in actual combat situations and in the potential for corrective action (in training emphasis, reorganization of task SOP or assigned responsibilities, etc.). From the methodologic viewpoint, the sensitivity of the FDC team simulation paradigm to such a subtle phenomenon demonstrates its potential for evaluating the degradation of performance produced by other environmental or modern battlefield stressors. A general supposition supported by these findings is that, when assessing military performance degradation, the quantity of work never completed may be more useful as an index of team capability and efficiency than increased errors or latencies.

Relationships between the observed changes in team preplanning activity and patterns of verbal activity within the team were also investigated. To perform communications analyses, team communications during lulls were transcribed from audio records. All utterances were divided into communication units (CU) i.e., sounds or words that convey a single thought, meaning or action (9). Standard communications in the processing, computing and transmission of firing data were identified and classified as Task SOP CU. After identification of all Task SOP CU, remaining CU were labeled as All Other CU. (including talk about the task which was not part of the standard, formal process). Procedural accuracy in scoring was insured by comparing data from two independent transcribers/scorers and resolving discrepancies. Video records were viewed before scoring.

Figure 4 shows total CU for Teams 1, 2, and 4 each 6 hours (i.e., the sum of CU during the two lulls). Total communications declined with increasing hours in all three teams. Maximum CU ranged from 850-1200 (two lulls combined). Minimum values for each team were approximately 50% of maximum. Task SOP and All Other CU components are also shown. Task SOP CU usually occurred if a team had preplanned activities left to perform during the lulls.

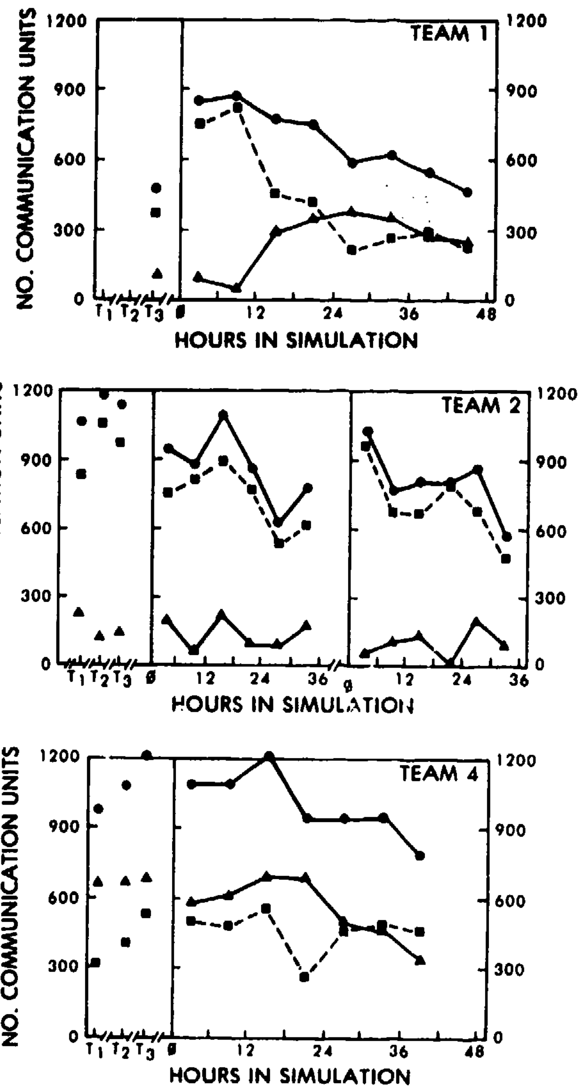

Figure 4. Group communication units (CU) during two 12-minute lulls each 6 hours are shown as a function of increased hours in the simulation. Total CU (solid circles), Task SOP CU (solid triangles), and All Other CU (solid squares) are shown.

Shown in Figure 5 are unprocessed preplanned demands and task ratio functions for each team with hours in the simulation. The former measure is the total number of targets not completed from the preplanning, prioritizing, and revising tasks; the latter indicates the relative preponderance of Task SOP CU to All Other CU, i.e. No. Task SOP CU/No. All Other CU. Larger task ratios do not indicate a greater absolute amount of work performed, but rather the relative preoccupation in the work.

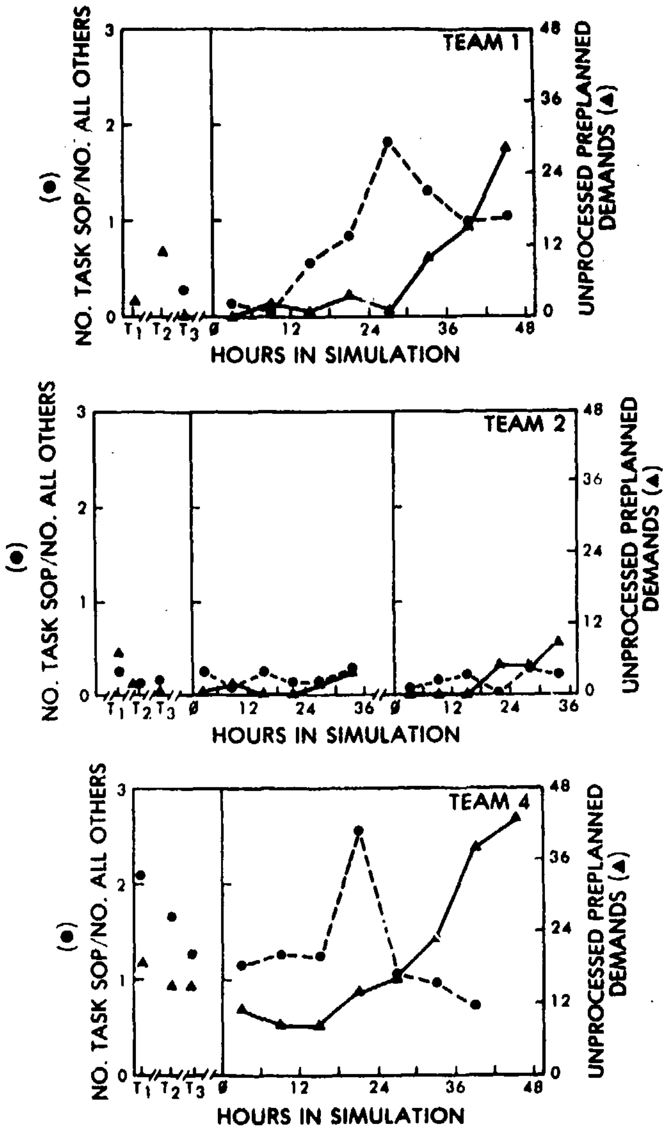

Figure 5. Task ratios (solid circles) and number of unprocessed preplanned demands (solid triangles) are shown for Teams 1, 2 and 4 as a function of hours in the simulation. Unprocessed preplanned demands are the sum of any revising, preplanning, and prioritizing targets which were not completed by each team. Increased task ratios indicate a greater preponderance of Task SOP CU to All Other CU.

Teams 1 and 4 differed markedly from Team 2 in how they used the lulls. Team 4 from the outset and Team 1 after 12 hours engaged heavily in Task SOP CU. Number of Task SOP CU and task ratios increased up until 24-30 hours, but then decreased again. Meanwhile unprocessed task demand began to rise precipitously (after 18 hours in Team 4; after 30 hours in Team 1), indicating work never accomplished; these trends eventually resulted in serious operational failures in preplanned target servicing. The decreases in task-ratio reflected the fact that, even though total communication was declining, fewer task communications followed SOP. Although teams often remained concerned with task requirements, their behaviors were much less task-directed and their nonstandard "task" communications reflected this. Such deviations sometimes resulted in confusion; increased effort and attention were then required for processing task demands. Also individuals began to discuss other topics.

Team 2's data are in marked contrast to those just described. Generally Team 2 used the lulls to relax and interact with each other; their task ratios were ≤ 0.3. As cited previously, Team 2 was more proficient at preplanning; hence they had more "reserve time" and seldom had to use lulls to do preplanning.

Increased Task SOP CU are likely a compensatory reaction. In this simulation where external task demand was held constant over time, increased work in lulls resulted from reduced individual and team efficiency and the recognition that more preplanning demands remained to be completed. In Teams 1 and 4, increased task ratios were evident by 30 and 18 hours, before unprocessed demands increased substantially. Later, when each team's compensations were no longer adequate to oppose the increased amounts of uncompleted demands, compensatory behaviors were reduced.

These interaction data suggest that teams and their predominant activities can be characterized by communications occurring during "lull" intervals. Furthermore, the number and type of communications bear some relationship to operational and performance capabilities. The contributions of various individuals to each group's communications and the affective quality of their communications are being explored. As reported elsewhere (10), and in this Annual Progress Report under WU 026, DAOG 0705, page 27. Interaction Process Analysis documented a progressive fall in the number and percentage of affectively positive CU in Teams 1 and 2 (coupled with a rise in negative CU in Team 2). These trends in group social support behavior may have contributed to observed crises of confidence and to a decision to withdraw from the simulation. Ultimately these indices of changing social interaction may be arrayed with physiological, biochemical, individual performance and team output measures to give insight into how these variables interact in conditions of environmental and task stress and altered sleep-rest schedules.

Presentations:

1. Banderet, L. E. Invited lecture, Simulated, Sustained Combat Operations in the Field Artillery Fire Direction Center, NARADCOM Chapter of Sigma Xi, Natick, MA, April 1980.

2. Banderet, L. E. and J. W. Stokes. Simulated, Sustained Combat Operations in the Field Artillery Fire Direction Center: A Model for Evaluating Biomedical Indices. Army Science Conference, West Point, NY, June 1980.

Publications:

1. Banderet, L. E., J. W. Stokes, R. Francesconi, D. M. Kowal and P. Naitoh. Artillery Teams in Simulated, Sustained Combat: Performance and Other Measures. In: Proceedings, Symposium on Variations in Work-Sleep Schedules. National Institute for Occupational Safety Health, Washington, DC., in press.

2. Banderet, L. E., J. W. Stokes, R. Francesconi, D. M. Kowal and P. Naitoh. Artillery Teams in Simulated, Sustained Combat: Performance and Other Measures. In L. C. Johnson, D. I. Tepas, W. P. Colquhoun, M. J. Colligan (eds.) The 24-Hour Workday. A Symposium on Variations in Work-Sleep Schedules. New York: Spectrum Publishing Inc., in press.

3. Banderet, L. E., J. W. Stokes, R. Francesconi and D. M. Kowal. Simulated, Sustained-Combat Operations in the Field Artillery Fire Direction Center (FDC): A Model for Evaluating Biomedical Indices. In: Proceedings, 1980 Army Science Conference, West Point, NY, Vol I:767-781.

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10. Banderet, L. E. and J. W. Stokes. Interaction process analysis of FDC teams in simulated, sustained combat. In: Proceedings, NATO Symposium on Motivation and Morale. Brussels, Belgium, 1980, in press.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	055 Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations
Study Title:	An Exploratory Investigation of Environmental, Demographic and Psychological Factors Related to Morse Code Radio Monitor Training
Investigator:	Bernard J. Fine, Ph.D.

Background:

The Army Intelligence School, Fort Devens, MA (USAISD) trains Army enlisted personnel to monitor Morse Code radio transmissions (MOS 05H). The course is highly structured, partially automated and self-paced, taking an average of 6 months to complete. The job demands a high degree of perceptual vigilance, typing skill, and self-motivation because of the extreme amount of repetition involved and the fact that the monitors have no knowledge of the contents of the communications they record. The training program is very fatiguing, mentally, and is susceptible to thermal stress even in the classroom. Student attrition is high, resulting in considerable waste of time and money.

Many graduates of USAISD are assigned to fixed facilities where, in the event of war, they may have to take defensive measures against chemical-biological warfare threats, measures which themselves impose thermal stress or tend to impair performance. Other USAISD graduates are assigned to mobile field units where they may also work in uncomfortable or hazardous climates. It is essential to national security that these key personnel be able to maintain accurate, thorough radio monitoring performance under such adverse conditions.

Progress:

Discussions were held with the Director of Training and the Chief of the Morse Code Division. They were interested in cooperating with any USARIEM studies which could help them predict who would be the most effective 05Hs under stress and which would reduce the attrition rate by prior screening. By mutual agreement, a pilot study was designed and a research protocol was prepared. New students (who arrive at Fort Devens in small groups each week) will participate as informed volunteers. In a 2-3 hour block of testing, the USARIEM investigators will obtain potentially relevent demographic and background information from each subject, plus scores related to personality, cognitive style, perceptual motor skill and other behavioral factors. This data will be related to the environmental reports and the quantitative assessments of each individual's progression through the course to be provided by USAISD (who will have no access to the priviledged information obtained by USARIEM).

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	055 Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations
Study Title:	Army Teams in Simulated Combat: Extramural Explorations
Investigator:	James W. Stokes, LTC(P), MC

Background:

Because team task organization, level of training, professional identity and group motivation are such crucial factors in preserving performance under extreme stress, many questions of great importance to the Army can only be answered by complex, "realistic" full-mission simulations. Some of the current questions of highest priority fall within the mission responsibility of Medical Research and Development Command. For example, will the well-known autonomic and mind-altering side effects of the antidotes for nerve-gas make them temporarily incapacitating (and if so, for what specific functions and for how long)? Or will highly motivated Army teams be able to maintain adequate output through improvisation, task-sharing, double-check procedures and interpersonal "reality-testing."

Although the need for full mission simulations exists, they demand military technical expertise, personnel and equipment which Medical Research and Development Command may be unable to mobilize within its own resources. Meanwhile, other Army Research, Development, Test and Evaluation (RDTE) agencies already exist whose principle function is to conduct realistic field experiments to test equipment, tactical doctrine or force structure. Many of their test issues have embedded in them questions of human capabilities under environmental stress, heavy physical work or psychological fatigue. USARIEM's experience in planning and conducting the FDC team simulation studies may be useful to those other agencies in obtaining the broadest and most valid possible results from their field studies.

One future option may be to task such agencies through the Test Schedule and Review Committee (TSARC) process to conduct high priority biomedical studies, with USAMRDC and/or the Academy of Health Sciences as proponents. Another alternative may be to design collaborative research studies around the complex simulation devices and systems which have been or are being developed for training. Over the past three years, exploratory efforts supported by this work unit have established contact with some of the agencies outside of USAMRDC who could be involved.

Progress:

In 1979, USARIEM was invited by the TRADOC Combined Arms Test Activity (TCATA) to participate in the design of a Field Artillery Crew Test (FACT). That test was proposed by TRADOC to determine whether the TO&E crews of the 155mm self-propelled howitzer are sufficient to sustain high rates of fire and movement for eight days of sustained operations. The Combat Developments Directorate, US Army Field Artillery School (USAFAS, proponent for studies related to the Field Artillery) has maintained that the FACT needs to address not only the howitzer crew but other elements of the system at the battery level, i.e. the FDC, command/control, survey, ammunition resupply, mess and maintenance assets. They also feel strongly that the test must involve live fire. In June 1980, USARIEM provided comments to USAFAS for their draft Independent Evaluation Plan (IEP) and reviewed a broad range of methods (physical fitness testing, urine and blood assays, medical records maintenance, systematic observations and surveys) which could quantify different aspects of fatigue during the field test. USAFAS regards the assessment of human fatigue due to the heavy physical workload, sleep-deprivation, task mental demands, noise and other environmental factors as critical to the success of the test; however, the measurement techniques must not interfere with the operational performance required by the scenario. TRADOC has approved the USAFAS IEP, but TCATA now indicates it cannot schedule the test before FY '82. We expect to be involved in preparation of the Test Design Plan (TDP) and Detailed Test Plan (DTP).

USARIEM has maintained contact with TCATA, and observed their field test methodology throughout two 72 hours iterations of the Mechanized Infantry in Smoke Environment (MISE) test (Mar-May 1980). TCATA specializes in "force-on-force" field experiments in which units from platoon to battalion size "battle" each other for up to 6 days using eye-safe laser designators and detectors on their weapons and vehicles. TCATA's computer assesses casualties in real-time and can also plot the position of all instrumented "players" on the Fort Hood reservation. The tactics used by each side may be relatively unconstrained or may be strictly defined by the exercise scenario (as was the case in MISE). The MISE test trials which were observed were conducted under difficult conditions for the instrumentation as well as for the troops (cold rain and mud, compounded by frequent use of chemical smoke as part of the test design). The observations therefore highlighted both the virtues and limitations of TCATA's methodology. USARIEM also assisted the Medical Safety Officer for the MISE test to maintain surveillance of any medical problems which might be caused by the chemical smoke if troops failed to follow the prescribed precautions.

TCATA will be conducting field portions of Operational Test (OT) III for the XM-1 Tank through May 1981. The test plan currently includes extensive periods in which the crews must function in chemical protective ensemble. USARIEM could therefore contribute both to safety planning and to data collection and interpretation.

Contact has also been established between USARIEM and the Human Factors Branch, Combat Developments Experimentation Command (CDEC), Fort Ord, CA. CDEC conducts force-on-force live field tests at their instrumented range at Fort Hunter-Liggett, CA. CDEC's trials differ from TCATA's long field exercises, and are instead short (less than 1 hour) set-piece "battles" or encounters. These trials are repeated many times with variations according to complex experimental designs. CDEC studies such as ARMVAL (Advanced Anti-Armor Vehicle Evaluation) could, with minor modification of methodology and test design, quantify performance degradation due to fatigue, chemical protective measures or other biomedical factors.

Another potential site for collaborative research is the Combined Arms Tactical Training Simulator (CATTS), operated by the Combined Arms Training Developments Activity (CATRADA) at Fort Leavenworth, KA. CATTS is a computer-driven battle simulation to which battalion comand groups from active Army and National Guard Units come to train in 2-3 day (usually 8 hour/day) exercises. The battalion commander and his staff function in mock-ups of their field settings and interact in real time with enemy and friendly forces (played by the computer and its operators). Several standard scenarios are available for desert (Suez Canal) and central European conditions. The Fort Leavenworth field unit of the US Army Research Insitute for Behavioral and Social Sciences (ARI) has been developing improved means of assessing command group performance in CATTS (1).

A CATTS battalion command group exercise was observed. Clearly, many changes in procedure would be needed to convert CATTS into a research tool with the quantitative precision approaching that of USARIEM's FDC team simulations. However, CATTS could be utilized with little change as a valuable demonstration/training vehicle for such problem areas as command/staff functioning in chemical protective uniforms in temperate or warm conditions. Incorporation of such a condition in a multi-factorial study design proposed by the ARI group could derive more systematic information. The chief of CATTS has expressed his willingness to support any collaborative research which can be done using CATTS, compatible with its training mission. Within several years, an improved version of CATTS, ARTBASS, will be able to travel to Army posts or laboratories; its potential should be developed as a research tool and as a means of teaching command groups how environmental hazards or chemical defense must be coped with in their operational planning.

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Animal Care and Animal Modeling

Background:

Over the years, the position of Chief, Animal Care Unit has expanded to include several areas of responsibility. These responsibilities include:

1) surgical development of new and unique animal models to support the research mission of the US Army Research Institute of Environmental Medicine (USARIEM),

2) performance of both chronic and acute aseptic surgical techniques and procedures to produce statistically significant numbers of healthy animal models,

3) administrative management of the Animal Care Facility to include the physical plant and animal care personnel in accordance with standards of the American Association for the Accreditation of Laboratory Animal Care (AAALAC),

4) maintenance of the health of the laboratory animal population through a sound conditioning program, a preventative medical program for all animals and the observation, diagnosis and treatment of medical/surgical problems occurring in the laboratory animal population, and

5) chairing of USARIEM's Animal Use Committee to review and make recommendations to the Commander for his approval or disapproval of proposed research protocols utilizing laboratory animals.

Progress:

1. Veterinary Support

The procedure for carotid body denervation was performed on four goats. They were used successfully on the study titled, "Role of Cerebral Fluids in Respiratory Adaptations to Acute Acid-Base Imbalance" by Dr. Fencl. Cisternal Magna Cannulas were implanted in two new goats. Respiratory responses to hydrogen cyanide (HCN) was surgically eliminated with the denervation but retest some months later indicated a return of HCN response. A redenervation procedure was attempted but was unsuccessful.

Four carotid loops were prepared on goats for a study titled, "Phenytoin as a Possible Therapeutic Agent in the Reduction of High Altitude Pulmonary Hypertension."

Implantation of arterial line and Swanz-Ganz catheterization were performed in the altitude chamber for the study entitled, "Phenytoin as a

Possible Therapeutic Agent in the Reduction of High Altitude Pulmonary Hypertension."

Konigsberg pressure transducers were implanted in the left ventricle of 8 dogs after splenectomy for the study titled, "An Evaluation of Various Methods of Rewarming Hypothermic Victims."

Surgical procedures, their numbers, the species involved, and the nature of their use (acute or chronic) performed in support of USARIEM protocols are listed in Table I.

TABLE I

Surgical Procedures Performed to Support Research During FY80

Surgical Procedures	Species, Number of Procedures Acute or Chronic Preparations		
	Caprine	Chronic	Acute
Cisternal Magna Cannula		2	
Carotid Loop		4	
Denervation		4	
Klonigsberg thoracotomy		8	
Splenectomy	Canine	6	
Swanz-Ganz Catheterization		Numerous	

2. Animal Use Committee.

The Animal Use Committee, continuing in its responsibility to: 1) oversee the use of laboratory animals and to insure that the information sought by the use of laboratory animals is sufficiently important to warrant their use, 2) insure that the maximum amount of information consistent with good scientific research practices is obtained, 3) use the minimum number of animals necessary for scientific validity, 4) after adequate consideration of the experimental design, laboratory limitations and alternative species, select the species most suitable, and 5) insure that the description of the procedures is reasonably complete and minimizes pain and discomfort to the greatest extent possible without compromising the objectives; reviewed the following protocols:

1. "Plasma Volume Expansion: A Potential Common Denominator in Exercise Endurance and Resistance to Heat Injury" - CPT Sandel

2. "Role of Carotid Bodies in Respiratory Adaptations to High Altitude" - Drs. Fencl, Gabel, Donovan

3. "In Vivo Effect of 2,3-Diphosphoglycerate on Factor VIII Procoagulant and Factor VIII Von Willebrand Activities" - CPT Gadarowski, CPT Scelza

4. "Neural Influences in Cold Induced Vasodilation" - CPT Ohata

5. "Alterations in Fluid and Electrolyte Balance in Hypothermic Dogs" - CPT Barr

6. "Phenytoin as a Possible Therapeutic Agent in the Reduction of High Altitude Pulmonary Hypertension" - Dr. Inge

7. "Heat Injury: Studies on Mechanisms, Prevention, and Predisposition" - Dr. Francesconi

3. Animal Care

To maintain and guarantee health of the laboratory animals, we have conducted a preventative medicine and conditioning program for each of the species. Incoming canines were examined, tatooed and dewormed upon arrival. A routine blood workup on each dog consisted of a CBC, heartworm exam and 16 parameter biochemical screen. Routine fecal analyses were performed on the dogs at six month intervals and appropriate antihelmintic therapy instituted. Rats were routinely histologically screened for the presence of pneumonitis and examined for pinworm infection. Newly arrived goats were examined, deloused, dewormed and routine blood work consisting of a CBC and 16 parameter biochemical screen was performed.

Table 2 summarizes animals procured, housed and cared for during FY 80.

TABLE 2

Animals Cared for During FY79

	Average Daily	Annual
Goats	10	20
Dogs	15	40
Rabbits	20	60
Cats	5	40
Rats	150	1400

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
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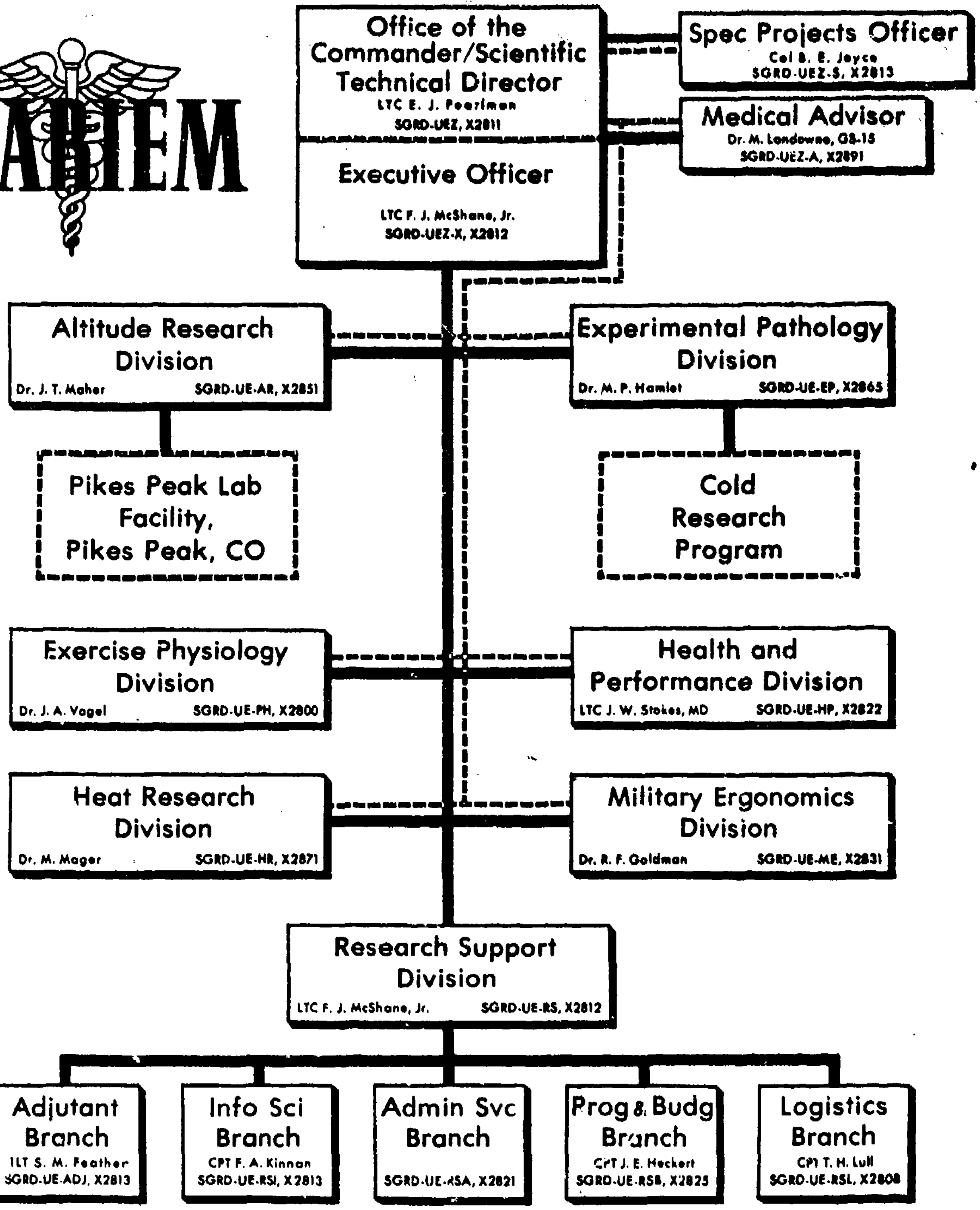
USARIEM



APPROVAL: Eliot J. Pearlman

Eliot J. Pearlman,
LTC, MC
Commanding

DATE: 21 July 1980

COMMAND

TECHNICAL COORDINATION

APPENDIX B

PUBLICATIONS

Banderet, L. E., J. W. Stokes, R. Francesconi and D. M. Kowal. Simulated, sustained-combat operations in the field artillery fire direction center (FDC): A model for evaluation biomedical indices. In: Proceeding 1980 Army Science Conference, West Point, NY, 1:167-181, 1980.

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APPENDIX C

ABSTRACTS AND PRESENTATIONS

Avellini, Barbara A. The effect of physical training in water or on land on heat tolerance. 20th Annual Brouha Work Physiology Symposium, Boston, MA, 17-19 September 1980.

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APPENDIX D

CONSULTATIONS

Legend

ALTITUDE RESEARCH DIVISION	AR
EXERCISE PHYSIOLOGY DIVISION	PH
EXPERIMENTAL PATHOLOGY DIVISION	EP
HEALTH & PERFORMANCE DIVISION	HP
HEAT RESEARCH DIVISION	HR
MILITARY ERGONOMICS DIVISION	ME

Requesting Individual/Agency	Subject	Division	Month
Boston Biomedical Rsch Inst Boston, MA	Energy cost and EMB of leg movement	PH	January
COL W. Carpenter US Army Institute of Dental Research Washington, DC	Assistance to USAIDR'S observational survey of dental problems and chapped lips during REDCOM exercise Empire Glacier '80.	HP	January
Lt. Horne Preventive Medicine Sect. 5th Infantry Div. Ft. Polk, LA	Developing form of heat doctrine for dissemination to troops	HR	January
DOD MC Officers Harvard School Public Health 677 Huntington Avenue Boston, MA	Altitude research mission and program	AR	January
HQDA-ODCSPER Pentagon Washington, DC	Footwear, gait, injuries	PH	January
HQ-TRADOC Ft. Monroe, VA	Physical Training Program	PH	January
MAJ Shirrilla Ft. Rucker, AL	Frostbite injuries in connection with jet fuel handling	EP	January

Requesting Individual/Agency	Subject	Division	Month
Office of Personnel Management, Medical Director Washington, DC	Physical fitness requirements and selection	PH	January
US Park Service Washington, DC	Physical fitness requirements and selection	PH	January
CPT K. Wyant Food Sciences Lab NLABS, Natick, MA	Use of environmental symptom questionnaires and ambulatory physiological recorders (MEDILOGS) during FSL study of dietary effects on Marines undergoing cold weather mountain training; MEDILOGS loaned to FSL for study	HP	Jan-Mar
Dr. Peter Buck Institute for Defense Analysis Arlington, VA	Palatability of water contained in POL bulk carriers	HR	February
HQ DARCOM DACDE-L (Loretta Gellner) Alexandria, VA	Request for briefing document on analysis of current doctrine in use for the Joint Chiefs of Staff	HR	February
HQ-FORSCOM Surgeon Ft. McPherson, GA	Running footwear	PH	February
MAJ G. Glann, Combat Development Directorate, US Army Field Artillery School Fort Sill, OK	FDC Team Study findings of performance degradation in sustained operations, for citation in Human Dimensions task group working paper, "Functional Assessment"	HP	Feb-Mar
Mr. George Goodwin Foreign Science & Technology Cntr. Charlottesville, VA	Field water requirements	HR	February
CPT J. Hopkins Combat Development Directorate, Academy of Health Sciences, Fort Sam Houston, TX	Documentation for the requirement of 2 medics, 2 ambulances with drivers for the 155 mm SP howitzer battery in the Division '86 TO&E	HP	February

Requesting Individual/Agency	Subject	Division	Month
Dr. Gerald Klein Augusta General Hospital Brunswick, ME	Rewarming techniques in emergency room treatment of hypothermia victims (2 fishermen submerged in freezing water)	EP	February
LTC Paul Martin HHC, 1st COSCOM Ft. Bragg, NC	Information regarding preparation of Brave Shield XVI	HR	February
Dr. John B. O'Sullivan USAMERADCOM Ft. Belvoir, VA	Information regarding water logistics	HR	February
Walter Reed Army Inst of Research Div. of Preventive Medicine Washington, DC	Physical fitness requirements and medical safety	PH	February
US Army Field Artillery School Ft. Benning, GA	MOS fitness requirements	PH	February
US Army Infantry School Ft. Benning, GA	Physical training program	PH	February
LTC Charles E. Blanchard Manpower Policy Division J-5 Organization Joint Chiefs of Staff Washington, DC	Problems of heat, British Army during WWII	HR	March
Defense Civil Inst of Environmental Medicine Toronto, Canada	Gender-free fitness standards	PH	March
Mr. George Goodwin Foreign Science & Technology Cntr. Charlottesville, VA	Soviet intelligence reports	HR	March
Col. Hall Pentagon Washington, DC	Wanted information on and a copy of the Israeli Briefing Report	HR	March
LTC Frank McGurk Chief, Combined Arms Tactical Training Simulator, CATRADA, Ft. Leavenworth, KA	Potential uses of CATTS Battalion Command Group training exercises in research and in training the implications of biomedical chemical protective measures on operations	HP	Mar-Jun

Requesting Individual/Agency	Subject	Division	Month
OTSG, Pentagon Washington, DC	Medical screening for fitness testing	PH	March
TRADOC Combined Arms Test Activity, Ft. Hood, TX	Prediction of heat stress in XM-1 crewmembers wearing chemical protective ensemble in the proposed OT III field test, May 1981.	HP	March
TRADOC Combined Arms 2d Armored Div Surgeon and Medical Personnel of the 1-5th CAV Bn Ft. Hood, TX	Systematic monitoring of medical complaints of troops in the Mechanized Infantry in Smoke Environments FDTE study	HP	Mar-Jun
Combat Developments Directorate, US Army Field Artillery School Ft. Sill, OK	Comments to the draft "Independent Evaluation Plan for the Field Artillery Crew Test (FACT)", "Assessment of physical factors and fatigue in a Field Artillery Crew Test (FACT) of sustained high-mission-load operations," and "Rates of fire for the FACT" (memos dtd 26-27 Jun)	HP	Apr-Jun
Drs. George Fielding Ralph Little Naval Research Laboratory Washington, DC	Navy CW Protective Clothing	ME	April Ongoing
HQ-TRADOC Ft. Monroe, VA	Footwear for training	PH	April
COL John MacDougall Canadian Liaison Officer Dr. Norman Quinn, British Liaison Officer	Altitude research mission and program	AR	April
Dr. Carlos Monge, Professor School of Medicine Universidad Peruana Cayetano Heredia Lima, Peru	Medical and performance problems at altitude	AR	April
MAJ Nelson Training Development Institute, TRADOC, Ft. Monroe, VA	Upgrading the teaching of stress management in the curriculum for drill sergeants	HP	April

Requesting Individual/Agency	Subject	Division	Month
Dr. A. Weisz, Hughes Industries Inc.	Protective Clothing Capability for Roland Missile Project	ME	Apr-Ongoing
Andrulis Research Corp. Bethesda, MD	Infantry MOS fitness requirements	PH	May
Baker River School Wentworth, NH	Exercise physiology	PH	May
Chief, Human Factors Br DCSEX, Combat Development Experimentation Command, Ft. Ord, CA	Assessment of fatigue and thermal stress in CDEC field studies	HP	May
Dr. Deirdre Cristenberry US Army Environmental Hygiene Agency Edgewood Arsenal Aberdeen, MD	Monitoring carbon monoxide levels in battle tanks	AR	May
Dr. Hayes FORSCOM Ft. McPherson, GA	Near drowning and water immersion	EP	May
Institude of Human Performance Fairfax, VA	Fitness requirements	PH	May
Mr. Carl Maresh University of Wyoming Laramie, WY	Recent improvements in USARIEM's Environmental Symptoms Questionnaire. Copies sent	HP	May
US Army Inf. School Ft. Benning, Ga	Fitness Standards	PH	May
Dr. Christopher Wall Thoracic Service University Hospital 80 East Concord Street Boston, MA 02118	Pulmonary diffusing capacity at high altitude	AR	May
Daniel L. Welch, Ph.D. Research Psychologist Andrulis Research Corp. Air Rights Building 7315 Wisconsin Avenue Bethesda, MD	Profile of the infantry soldier	AR	May

Requesting Individual/Agency	Subject	Division	Month
SP5 Branley Soldier's Magazine Cameron Station Alexandria, VA	Article on cold weather preventive medicine	EP	June
Mr. Tom Clemmons Reader's Digest	Article on hypothermia	EP	June
Director of Training and Chief Morse Division US Army Intelligence School Ft. Devens, MA	Impairment of student performance during periods of thermal stress in the MOS 05H classrooms; prediction of high student attrition	HP	Jun-Ongoing
Eisenhower Med Center Outpatient Psychiatry Ft. Gordon, GA	"Pro-Life" Program in 3rd Inf. Div. Germany	PH	June
Mr. John Frim DCIEM, Downsview Ontario, Canada	Cold research program	EP	June
Drs. Werner Gehrman, Johannes Mertman Federal Republic of Germany	Procedures for Physiological Protection	ME	June
Leo C. Senay, Ph.D. Department of Physiology St. Louis University Medical Center School of Medicine St. Louis, MO 63104	Role of arginine vasopressin in fluid shifts at altitude	AR	June
Dr. S. Marsh Tenney Department of Physiology Dartmouth Medical School Hanover, NH 03755	Red cell hemolysis at altitude	AR	June
Dr. Ann Berssenbrugge Department of Preventive Medicine, University of Wisconsin Center for Health Sciences 504 Walnut Street Madison, WI 53706	Periodic breathing and gas exchange during physiologic sleep at high altitude	AR	July
COL Francis J. Cadigan Jr.,MC DAO-AMLO Box 36 US Embassy APO, NY 09510	Altitude research mission and program	AR	July

Requesting Individual/Agency	Subject	Division	Month
Dr. A. Pharo Gagge, Assoc. Editor Journal of Applied Physiology: Respiratory, Environmental & Exercise Physiology John B. Pierce Foundation Laboratory 290 Congress Avenue New Haven, CT 06519	Manuscript review/ evaluation	AR	July
MAJ Garner Chief, Preventive Med. Sect. MEDDAC Ft. Sill Lawton, OK	Problems of operating in the heat	HR	July
General Elecric Lynn, MA	Lifting limits	PH	July
Dr. Melvin L. Henkin Inspir-Air Corporation 15549 Devonshire Street Mission Hills, CA 91345	Techniques for pre-acclimatizing to high altitude	AR	July
Massachusetts Rehab. Hosp. Pain Unit Boston, MA	Behavioral aspects of fitness	PH	July
Lt. Parker Redstone Arsenal Huntsville, AL	Heat related problems	HR	July
Dr. Gary Whitford School of Dentistry Department of Oral Biology-Physiology Medical College of Georgia Augusta, GA 30902	Alterations in urinary composition and drug excretion patterns at high altitude	AR	July
CPT Ed Wilson Chief, Preventive Med. Sect. Ft. Benjamin Harrison Indianapolis, IN	Problems or working in the heat	HR	July
Dr. John Berkowich DuPont	Flat Plate Measurements	ME	Aug-Ongoing

Requesting Individual/Agency	Subject	Division	Month
Dr. E. R. Buskirk, Assoc Editor Journal of Applied Physiology: Respiratory, Environmental & Exercise Physiology Laboratory of Human Performance Research 119 Noll Laboratory Pennsylvania State University University Park, PA 16802	Manuscript review/ evaluation	AR	August
Dr. John Claybaugh Clinical Investigation Svc Tripler Army Medical Center Tripler AMC, HI 96859	Medical aspects of high altitude exposure	AR	August
2LT L. Darrah, HQ ASD Dayton, OH	AF Women's Clothing	ME	August
MAJ Gary W. Gray, M.D. Defence & Civil Institute Environmental Medicine 1133 Sheppard Avenue West Downsview Ontario, Canada M3M 3B9	Measurement & analysis of subjective symptomatology of acute mountain sickness	AR	August
Ms Kate Olson Editor for Psychology Today	Clarification of issues and methods in the 1978 Evaluation of Women in the Army (EWITA) study	HP	August
MAJ Graham C. Adnams Australia	Physiological Evaluation Techniques	ME	September
Dr. A. Pharo Gagge, Assoc. Editor Journal of Applied Physiology: Respiratory, Environmental & Exercise Physiology John B. Pierce Foundation Laboratory 290 Congress Avenue New Haven, CT 06519	Manuscript review/ evaluation	AR	September
CPT R. M. Barry Toledo, OH	IDF desert operations	HR	September
82nd Airborne Division Surgeon Ft. Bragg, NC	Coronary risk factors	PH	September

Requesting Individual/Agency	Subject	Division	Month
LTC Wes Groesbeck RDJFT Washington, DC	H_2O problems in desert operations	HR	September
CDR Hall Dr. P. Naitoh Environmental Physiol Dept Naval Health Rsch Center San Diego, CA	Planned NHRC studies of physical work and sleep deprivaton, effects on military performance; possible future collaboration involving thermal stresses	HP	September
Mr. R. Hunter Pentagon Washington, DC	Issues in the 1978 Evaluation of Women in the Army (EWITA) study	HP	September
Dr. Eliezer Kamon Noll Lab Penn State U	EPRI Cooling System	ME	September
Ms. Harriet Meinander Finland Research Center	Clothing Comfort	ME	September
Mr. Tor S. Nilsen, Helly-Hansen and Mr. S. Siverterson Norway Embassy	Protective Suits	ME	September
1LT John O'Shaughnessy 1st Brigade 82nd Airborne Division Fort Bragg, NC 28307	Medical and performance problems at high altitude	AR	September
Dr. Harvey Perry Dept of Surgery Maine Medical Center Portland, ME 04102	Medical problems associated with exposure to high altitude	AR	September
Professional Management Assoc. Washington, DC	Fitness requirements for occupation	PH	September
COL Martin Rogers Washington, DC	H_2O problems in desert operations	HR	September
Dr. Socks Naval Submarine Rsch Lab Groton, CT	Cold weather research program	EP	September

Requesting Individual/Agency	Subject	Division	Month
LtCdr J. Socks & Drs K. Laxar, G. Moeller, B. Rogers Naval Submarine Medical Rsch Lab Grotor . CT	Methodology of surveys of medical problems, level of training and background factors during military cold weather exercises	HP	Sep-Oct
Dr. Margaret Tolbert Director, Carver Rsch Foundation of Tuskegee Institute Tuskegee, AL	Altitude research mission and program	AR	September
CPT D. F. S. Tollefson, MC APO Europe	Information regarding H_2O as a tactical weapon	HR	September
MAJ Wages USMC Washington, DC	Distribution and cooling of water	HR	September
CPT Boyles 4th Med Bn Ft. Carson, CO	Discuss medications and problems for deployment at Ft. Drum	EP	October
Dr. Hugh Crone MRL Australia	Physiological Test Methods	ME	October
CPT Czachowski Ft. Bragg, NC	Cold water immersion	EP	October
Mr. Myron Danield News Office Mass General Hospital Boston, MA	Article on hypothermia	EP	October
Lt. Davis Division Surgeon's Ofc 2nd Division Korea	Exposure time in cold	EP	October
DOD Pentagon Washington, DC	Obesity standard	PH	October
Dr. J. Dyer Army Rsch Inst of Behav & Soc Sci. Ft. Benning Field Unit	Team performance and training	HP	October

Requesting Individual/Agency	Subject	Division	Month
MAJ Richard M. Ely Foreign Science & Technology Center Charlottesville, VA	Water requirements and purification methods and standards of the USA and other countries	HR	October
CPT Fisher Cold Weather Prev Med Ofcr Academy of Health Sciences Ft Sam Houston, TX	Cold weather preventive medicine	EP	October
CPT Fisher Materiels Branch Combat Devel. Dir. Acad of Health Sci Ft. Sam Houston, TX	Requirements documentation for an I.V. warmer and a medics vest for use in cold weather operations	HP	October
General Rsch Corp. Washington, DC	Fitness requirements for occupation	PH	October
Dr. Herbert N. Hultgren Cardiology Division Stanford University Medical Center Stanford, CA 94305	Pathogenesis of high altitude pulmonary edema	AR	October
CPT Michael B. Kelley Sanitary Engineering Div. USA Environ. Hygiene Agency Aberdeen Proving Ground, MD	Discussion on revision of TB Med 229, with special emphasis on desert and jungle water requirements	HR	October
COL C. A. Kowalezyk Washington, DC	H_2O problems in desert operations	HR	October
Mr. Charles Pankow South America Reps P.O. Box 39583 Los Angeles, CA 90039	Body hydration and illness at high altitude	AR	October
CPT T. Savage USAVNC Ft. Rucker, AL	Ice vests	ME	October
US Army Infantry School Ft. Benning, GA	Staffing plan for Physical Training Unit	PH	October
Mr. C. Abrams Combat Developments Dir. US Army Field Artillery School Ft. Sill, OK	Medical and psychological implications of USAFAS's draft letter requirement for signature suppression kits for Pershing II electric generators	HP	November

Requesting Individual/Agency	Subject	Division	Month
Advanced Research Resources Organization Washington, DC	Occupational fitness requirements	PH	November
Air Force AF-MPC-RPQ Wright Patterson AFB, OH	Job Classification	PH	November
Mr. John Bonitatibus University of Southern California 12933 Erickson Avenue Downey, CA 90242	Self-paced exercise at high altitude	AR	November
Defense Civil Institute of Environmental Medicine Toronto, Canada	Fitness testing of personnel	PH	November
CPT M.J. Fisher Academy of Health Sciences Ft. Sam Houston, TX	Information regarding IDF desert operations; H_2O doctrine	HR	November
International Journal of Sports Medicine Mrs. Susan Peters Panoramastrasse 117 6900 Heidelberg West Germany	Manuscript review/ evaluation	AR	November
CDR M. Kerstein New Orleans, LA	Heat briefing - local elements 4th Marine Div.	HR	November
Mass. Inst. of Technology Cambridge, MA	Adult fitness testing	PH	November
Southeast Florida Institute Criminal Justice Florida	Occupational fitness requirements	PH	November
Mr. Jerry Stengel United States Department of the Interior Bureau of Mines Post Office Box 18070 Pittsburgh, PA 15236	Test requirements for closed-circuit respirators	AR	November
Mr. Steve Sternberg Medical Tribune	Antarctic medical care	EP	November
Uniformed Services Univ. of Health Sciences Bethesda, MD	Occupational fitness requirements	PH	November

Requesting Individual/Agency	Subject	Division	Month
Army Medical Equipment Test and Evaluation Center Aberdeen, MD	MOS lifting requirements	PH	December
Dr. Herbert Benson Beth Israel Hospital Boston, MA	India study	ME	December
LTC Brake TARADCOM	Chemical Protective Systems for all combat vehicles	ME	December
MAJ Furukawa Combat Devel Dir Acad of Health Sci Ft. Sam Houston, TX	Comments on Concept Paper on Theater of Operations Psychiatric Support Systems (TOPSS)	HP	December
General Accounting Office Washington, DC	Military medical enlistment standards	PH	December
Dr. Mayor Mary Hitchcock Hospital Hanover, NH	Female hypothermia victim	EP	December
Redstone Arsenal (Human Eng. Lab) Alabama	MOS lifting requirements	PH	December
Mr. Daniel Rosenberg Tufts Medford, MA	Energy costs	ME	December
Lt G. Shackford School of Aerospace Medicine Brooks, AFB, TX	MEDILOG ambulatory cassette recorders and related data acquisition devices	HP	December
US Army Modern Pentathalon Center San Antonio, TX	Fitness programs	PH	December
US Postal Service HQ Washington, DC	Occupational demands and testing	PH	December

APPENDIX E

BRIEFINGS

Francesconi, R. P. Doctrine of Soviet and Israeli heat procedures. 10th Special Forces Group (Airborne), Ft. Devens, MA, 31 March 1980.

Goldman, R. F. XM-1 tank study (thermal heat stress), The Pentagon, Washington, DC, 10 April 1980.

Goldman, R. F. XM-1 tank study (thermal heat stress), The Pentagon, Washington, DC, 3 October 1980.

Goldman, R. F. XM-1 tank study (thermal heat stress), The Pentagon, Washington, DC, 3 November 1980.

Hamlet, M. P. Cold weather preventive medicine. 25th Inf Div, Schofield Barracks, HI, 12-19 January 1980.

Hamlet, M. P. Cold weather preventive medicine briefing in support of Aviation Life Support Equipment Course, National Guard Professional Education Center, Little Rock, AK, 6-7 February 1980.

Hamlet, M. P. Cold weather preventive medicine briefing at Flight Surgeon's Course, Ft. Rucker, AL, 9-10 March 1980.

Hamlet, M. P. Arctic indoctrination training. 2-504th Inf, Ft. Bragg, NC, 20 March 1980.

Hamlet, M. P. Cold weather preventive medicine briefing in support of Aviation Life Support Equipment Course, National Guard Professional Education Center, Little Rock, AK, 9 July 1980.

Hamlet, M. P. Cold weather preventive medicine briefing at Flight Surgeon's Course, Ft. Rucker, AL, 25 September 1980.

Hamlet, M. P. Cold weather briefing, 10th Special Forces, Ft. Devens, MA, 30 September 1980.

Hamlet, M. P. Cold weather preventive medicine briefing at Flight Surgeon's Course, Ft. Rucker, AL, 9-10 March 1980.

Hamlet, M. P. Cold weather preventive medicine. Intelligence School (USAISD), Ft. Devens, MA, 4-5 December 1980

Hamlet, M. P. Prevention and treatment of cold weather injuries, USMCR, Worcester, MA, 6 December 1980.

Hamlet, M. P. Cold weather preventive medicine. Cutler Army Hospital, Ft. Devens, MA, 12 December 1980.

Hubbard, R. W. Prevention of heat illness in hot environments. Flight Surgeon's Course on "Temperature Extremes", USAAMED Center, Ft. Rucker, AL, 10 March 1980.

Hubbard, R. W. Heat briefing on an analysis of current heat operations for the prevention of heat illness. 10th Special Forces Group (Airborne), Ft. Devens, MA, 31 March 1980.

Hubbard, R. W. Prevention of heat illness in hot environments. Flight Surgeon's Course on "Temperature Extremes", USAAMED Center, Ft. Rucker, AL, 25 September 1980.

Hubbard, R. W. How to prevent heat injuries in hot weather environments. Navy/Marine Reserve Center, Worcester, MA, November 1980.

Mager, M. Prevention of heat illness in hot environments. Flight Surgeon's Course on "Temperature Extremes", USAAMED Center, Ft. Rucker, Al, 17 November 1980.

Vogel, J. A. Gender free fitness standards and entrance screening. HQDA-ODCSPER, Office of the Deputy Chief of Staff for Personnel, The Pentagon, Washington, DC, 17 July 1980.

APPENDIX F

LECTURES

Banderet, L. E. Simulated, sustained combat operations in the field artillery fire direction center. Sigma Xi Invited Lecture, Natick, MA, 24 April 1980.

Bowers, W. D., Jr. Effects of heat on liver. Biology Colloquium, Wheaton College, Norton, MA, 30 October 1980.

Bowers, W. D., Jr. Effects of heat on perfused liver. Seminar, Tuskegee Institue, Tuskegee, Alabama, 6 November 1980.

Goldman, R. F. Military applied physiology, Uniformed Services University of the Health Sciences, Bethesda, MD, 27 May 1980.

Goldman, R. F. Military ergonomics, Uniformed Services University of the Health Sciences, Bethesda, MD, 3 June 1980.

Goldman, R. F. Tropical medicine, Walter Reed Army Institute of Research, Washington, DC, 17-18 August 1980.

Goldman, R. F. Occupational medicine, US Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD, 19 August 1980.

Hamlet, M. P. Hypothermia. Hypothermia and Cold Water Survival Conference, American Red Cross, Westchester County, NY, 28-29 March 1980.

Hamlet, M. P. Hypothermia. Hypothermia in the Urban Environment Conference, Emergency Medical Services Academy, Queens Hospital Center, Jamaica, NY, 23 February 1980.

Hamlet, M. P. Hypothermia. International Hypothermia Conference, University of Rhode Island, Marine Advisory Service, Kingstown, RI, 23-27 January 1980.

Hubbard, R. W. Heat injury prevention. Cutler Army Hospital, Ft. Devens, MA, 16 May 1980.

Hubbard, R. W. Prevention of heat illness. NLABS Explorer Scouts Post, Natick, MA, 5 June 1980.

Hubbard, R. W. The development of heatstroke model. Wheaton College, Norton, MA, 30 October 1980.

Mager, M. Effect of heat stress on man. Combined Grand Rounds, Department of Dermatology, Boston & Tufts University School of Medicine, Boston, MA, 26 March 1980.

Mager, M. Prevention and emergency treatment of heat illness in an industrial setting. Luke Mill of the Westvaco Corp., Luke, MD, 30 June 1980.

Maher, J. T. Maximal performance at high altitude. Presented at a Symposium jointly sponsored by the American College of Sports Medicine and the University of Louisville Graduate School on "Limiting Factors in Maximal Performance", 27 March 1980.

Stokes, J. W. Combat in extreme environments. AMED Short Course, Division and Combat Psychiatry, Monterey, CA, 29 April 1980.

Vogel, J. A. Physiology of exercise. Lectured here at USARIEM to Harwich High School class, Harwich, MA, 5 March 1980.

Wright, J. E. Muscle physiology. Boston University Graduate Seminar, Boston, MA, 19 March 1980.

Wright J. R. Physiology of exercise. Upper class and graduate biology students, Springfield College, Springfield, MA, 29 January 1980.

Wright, J. E. Strength training and muscle hypertrophy: A synthesis of theoretical and applied concepts. Graduate Course in Exercise Physiology, Boston University, Boston, MA, 2 December 1980.

APPENDIX G

MISCELLANEOUS

Breckenridge, J. R. Discussions with Director/Staff of Hohenstein Institute, (Re: Procedures for measurement of clothing protective parameters and development of a NATO publication on physiological evaluation of clothing.), Bonningheim, Federal Republic of Germany, 16-17 April 1980.

Breckenridge, J. R. Participate as US Correspondent to NATO MAS Committee, Cologne, Federal Republic of Germany, 21-25 April 1980.

Goldman, R. F. Chair Symposium "Man in the Cold", Am. Physiol. Soc., Toronto, Canada, 13-16 October 1980.

Goldman, R. F. Participate in Red Flag Exercise, Travis AFB, CA, 16-19 March 1980.

Goldman, R. F. Chair & Present NATO Advisory Group for Aerospace R&D Meeting (AGARD), Bodo, Norway, 18-23 May 1980.

Goldman, R. F. Conduct XM-1 Tank Study (Per request of Undersecretary for R&D Dr. LaBerge), Yuma, AZ, 2-11 September 1980.

Goldman, R. F. Attend Tri-Service Conference on Defense Against Chemical Agents, Reston, VA, 12-15 November 1980.

Goldman, R. F. Study Carrier operation aboard USS AMERICA, Norfolk, VA, 27-31 November 1980.

Mager, M. and R. P. Francesconi. Journal Review, Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology.

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